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# FORCE TESTS ON A SEPARABLE-NOSE CREW ESCAPE CAPSULE IN PROXIMITY TO THE PARENT FUSELAGE WITH COLD FLOW ROCKET PLUME SIMULATION AT MACH NUMBERS 0.3 THROUGH 1.2

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**ARO, Inc.**

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**June 1970**

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# NOTICES

# FORCE TESTS ON A SEPARABLE-NOSE CREW ESCAPE CAPSULE IN PROXIMITY TO THE PARENT FUSELAGE WITH COLD FLOW ROCKET PLUME SIMULATION AT MACH NUMBERS 0.3 THROUGH 1.2

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Earl A. Price, Jr.
ARO, Inc.

## FOREWORD

The work reported herein was done at the request of the Air Force Flight Dynamics Laboratory (AFFDL), Air Force Systems Command (AFSC), under Program Element 62201F, Project 1362.

The results of the test were obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates, Inc.), contract operator of the Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC), Arnold Air Force Station, Tennessee, under contract F40600-69-C-0001. The tests were conducted from March 24 through 31, 1970, under ARO Project No. PC0083. The manuscript was submitted for publication on May 15, 1970.

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This technical report has been reviewed and is approved.

George F. Garey
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Director of Test

## ABSTRACT

Static force tests were conducted on a separable-nose crew escape capsule in the presence of the forward section of an airplane fuselage. The capsule escape rocket exhaust plume was simulated with high-pressure air heated to a total temperature of approximately 100°F. Data were obtained at Mach numbers of 0.3, 0.6, 0.9, and 1.2 at capsule angles of attack from -15 to 22 deg and angles of sideslip from 0 to 15 deg for various positions of the capsule relative to the fuselage section. All testing was conducted with the fuselage at zero-degree angle of attack and zero-degree sideslip. Data were obtained both with and without rocket exhaust plume simulation. With the capsule at angle of attack, the most significant interference was on pitching moment. The most significant effects with the capsule at sideslip angles were on rolling and yawing moments. The magnitude and extent of the interference effects were larger with the jet on than with the jet off.

# CONTENTS



## APPENDIXES

## NOMENCLATURE

| | |
|---|---|
| A | Reference area (cross-sectional area at separation bulkhead), 22.608-in$^2$. |
| CD | Drag coefficient, drag/$q_\infty A$ |
| CL | Lift coefficient, lift/$q_\infty A$ |
| CM | Pitching-moment coefficient, pitching moment/$q_\infty A\ell$ |

| | |
|---|---|
| CML | Rolling-moment coefficient, rolling moment/$q_\infty A\ell$ |
| CMN | Yawing-moment coefficient, yawing moment/$q_\infty A\ell$ |
| CY | Side-force coefficient, side force/$q_\infty A$ |
| $\ell$ | Reference length, 16.5 in. |
| $M_\infty$ | Free-stream Mach number |
| $p_c$ | Jet chamber pressure, psia |
| $p_\infty$ | Free-stream static pressure, psia |
| $q_\infty$ | Free-stream dynamic pressure, psi |
| X | Longitudinal separation distance between the capsule and fuselage, in the wind axis, and measured from the capsule moment reference point before separation to the capsule moment reference point after separation, in. (Fig. 3) |
| Y | Lateral separation distance between the capsule and fuselage, perpendicular to the X-Z plane, and measured as noted for X, in. (Fig. 3) |
| Z | Vertical separation distance between the capsule and fuselage, perpendicular to the wind axis, and measured as noted for X, in. (Fig. 3) |
| $\alpha_c$ | Capsule angle of attack, deg |
| $\beta_c$ | Capsule angle of sideslip, deg |

# SECTION I
# INTRODUCTION

This investigation was conducted to provide aerodynamic data for investigating crew escape systems at transonic flight conditions. The interference effects upon the capsule due to both the proximity of the fuselage section and the cold air jet simulation of the separation rocket were determined. Static stability force and moment parameters were obtained on a separable-nose crew escape capsule supported from a remotely controlled system that positioned the fuselage section of the airplane with respect to the nose capsule and provided pitch or yaw of the capsule. The fuselage section position relative to the capsule was varied from approximately 14 in. aft to 17 in. forward of the capsule, and from 0 to 10 in. above the capsule. Laterally, the capsule was aligned with the fuselage for the pitch runs and was tested aligned and offset 5 in. to the side of the fuselage for the yaw runs. Data were obtained at capsule angles of attack from -15 to 22 deg and capsule angles of sideslip from 0 to 15 deg. The fuselage angle of attack and angle of sideslip were zero. Testing was conducted at nominal free-stream Mach numbers of 0.3, 0.6, 0.9, and 1.2 for both jet off and with air used to simulate the rocket jet plume.

Tests on this same model using the same support system have been conducted previously in the von Kármán Facility at Mach numbers 2 through 5. The results are presented in Ref. 1.

# SECTION II
# APPARATUS

## 2.1 TEST FACILITY

The Aerodynamic Wind Tunnel (4T) is a closed-loop, variable density tunnel. It can be operated at Mach numbers from 0.10 to 1.40 with a variable stagnation pressure from 300 to 3700 psfa at all Mach numbers. The test section is 4 ft square and 12.5 ft long with variable porosity walls (0 to 10 percent) and top and bottom walls that can be diverged or converged (±0.5 deg). The test section is completely enclosed in a plenum chamber from which the air can be evacuated, thus allowing part of the airflow to be removed through the test section walls. This design allows control of wave attenuation and blockage effects. Additional information on the tunnel may be found in Ref. 2. A schematic of the test section showing the location of the test model is shown in Fig. 1, Appendix I.

## 2.2 TEST ARTICLES AND SUPPORT SYSTEM

The separable-nose crew compartment escape capsule model and the fuselage section model, Figs. 2 through 4, were 1/10-scale models of the F-104 aircraft. The capsule had three wedge-shaped stabilizing booms extending to the rear. These booms (Fig. 2c) were positioned 120 deg apart, and the upper boom was fitted with a trim tab (Figs. 2a and b). The escape rocket nozzle was positioned in a cutout on the lower aft portion of the model (Fig. 2e) and was attached to the sting such that the model was isolated from the jet reaction force. Details of the nozzle are given in Fig. 2d.

The fuselage section details are given in Fig. 2f. As shown in this figure, a section of the fuselage front face formed a door. The door was opened to provide clearance for the capsule sting support when the capsule and fuselage were in close proximity. The two longitudinal slots in the fuselage and the cutout in the top of the door simulate the storage locations of the stabilizer booms while the aircraft is in normal flight. The cutout on the bottom of the fuselage is a relief for the escape rocket exhaust during initial firing.

Photographs of the capsule and fuselage section mounted on the support system are presented in Fig. 4. This support system allowed remote control of capsule attitude and the relative position of the capsule to the fuselage in three directions. Capsule pitch and vertical separation were accomplished with two pitch mechanisms (fore and aft, see Fig. 1) which for this test gave capsule angles of attack from -15 to 22 deg and vertical separations from 0 to 10 in. Longitudinal separation was accomplished by a drive mechanism which traversed the fuselage approximately 14 in. aft and 17 in. forward of the capsule. For capsule sideslip data, both models were rolled 90 deg on the support system in order to use the pitch mechanisms to yaw the capsule. A drive mechanism which traversed the capsule laterally with respect to the fuselage was used to obtain data at Z = 6 in. when the models were rolled 90 deg.

## 2.3 INSTRUMENTATION

Capsule force measurements were made with a six-component, moment-type, strain-gage balance. The model attitude and position were determined from calibrated potentiometers. Jet chamber pressure was measured with a 1000-psia transducer which is considered accurate to within one percent of capacity. One static pressure measurement was obtained at the base of the model. Electrical signals from

the balance, pressure transducers, and potentiometers were digitized and recorded on magnetic tape as well as fed directly to a computer for on-line data reduction. The balance outputs were also recorded on an oscillograph for monitoring of model dynamics.

# SECTION III
# TEST DESCRIPTION

## 3.1 PROCEDURE

Data were obtained at nominal free-stream Mach numbers of 0.3, 0.6, 0.9, and 1.2. The simulated altitude and jet chamber to free-stream static pressure ratio for each Mach number are presented in Table I (Appendix II). A comparison of the full-scale plume shape and the model plume using air is shown in Fig. 5. A summary of the model attitudes tested is presented in Table II. The capsule attitudes and positions in this table are nominal values which do not include deflections of the sting and balance. Each group of data was obtained by setting $\alpha_c$ or $b_c$, Y, and Z and varying X. All testing was conducted at a fuselage angle of attack and angle of sideslip of zero. In order to obtain data more rapidly, X was varied continuously as data were being taken. The longitudinal separation (X) was varied from approximately -14 to 17 in. except when limited due to model fouling. For each test condition and model attitude, data were recorded for both jet-off and jet-on conditions. All data were taken with the door on the fuselage front face closed except when clearance was necessary for the capsule sting.

## 3.2 DATA REDUCTION

Measured force and moment data were reduced to coefficient form in the stability axes system. The moments were transferred to the moment reference station shown in Fig. 2a. A base drag correction was made for the balance cavity area only.

## 3.3 PRECISION OF MEASUREMENTS

An estimate of the precision of the data is presented in Table III for Mach numbers 0.6 and 1.2. The estimated accuracies of the coefficients were computed by the law of propagation of errors.

# SECTION IV
# RESULTS AND DISCUSSION

The objective of this investigation was to obtain aerodynamic force and moment data on a separable-nose escape capsule to determine interference effects caused by the fuselage and the rocket exhaust plume. The capsule and fuselage models were 1/10-scale components of the F-104 aircraft; however, the test was conducted as a general investigation of separable-nose crew escape systems.

Presented in Table II is a summary of all model attitudes and positions at which data were obtained. A complete set of plots for all model attitudes were furnished AFFDL as well as plots of the coefficients $\alpha_C$ and $\beta_C$ to aid in their analysis of the results.

Data are presented in Figs. 6 through 9 showing the lift, drag, and pitching-moment characteristics of the capsule with the jet off for Mach numbers 0.3, 0.6, 0.9, and 1.2, respectively.

The most significant interference effect was on pitching moment. As the fuselage approached the capsule from the most negative X position (position of least interference), there was a decrease in pitching moment with the lowest values occurring between X = -4 in. and X = 0 in. This results from the flow field of the fuselage section acting on the trailing booms and aft portion of the capsule. As the fuselage was traversed further in the positive direction, the pitching moment increased and for Z = 6 in. and 10 in. reached a positive peak as the high pressure air region moved toward and passed the moment reference point. There were moderate interference effects on lift and drag with maximum values occurring in the vicinity of X = 0. A comparison of the data at the different Mach numbers indicates that the interference effects became more severe as Mach number was increased.

Presented in Figs. 10 through 13 are the lift, drag, and pitching-moment characteristics of the capsule with the jet on to simulate the escape rocket exhaust plume. The trends in the data were similar to those for the jet-off condition; however, some differences were noted. The interference effects were of greater magnitude, and the peaks in the pitching moment and lift occurred at slightly greater separation distances than those obtained with the jet off. This was attributed to the jet impinging on the forward portion of the fuselage section, causing a larger and stronger region of interference. The largest effects were at Mach number 0.3.

Data are presented in Fig. 14 showing the side-force, yawing-moment, and rolling-moment characteristics of the capsule in the sideslip attitude. The most significant interference effects were on the moment coefficients where the interference increased with angle of sideslip. The effects on rolling moment are attributed to the flow field from the fuselage model acting on the lower trailing booms. As angle of sideslip was increased, the lower left boom extended farther aft and toward the path of the fuselage section, and the right boom moved forward and away from the fuselage. As the fuselage traversed toward the capsule, the flow-field first acts upon the left boom, inducing a positive rolling moment, and then on the right boom, producing a negative rolling moment. The yawing moment increased to a peak when the fuselage passed over the aft portion of the capsule and then decreased as the fuselage was traversed toward the capsule nose.

In Fig. 15, data are presented for the capsule in the sideslip attitude with the jet on. As was the case with the capsule in the pitch plane, the trends were similar to the jet-off data although the magnitude and extent of the interference effects were greater.

## SECTION V
## CONCLUDING REMARKS

The results of a test conducted at Mach numbers from 0.3 to 1.2 on a separable-nose escape capsule to determine the interference effects due to both the proximity of a fuselage section and capsule rocket exhaust plume led to the following concluding remarks. With the capsule at various pitch angles, the most significant interference effect was on pitching moment. With the capsule at various sideslip angles, the interference effects were largest on the rolling and yawing moments. The magnitude of the interference effects was larger and extended over a larger region with the jet on.

## REFERENCES

1. Jones, Jerry H. and Jenke, L. M. "Force Tests on a Separable-Nose Crew Escape Capsule in Proximity to the Parent Fuselage with Cold Flow Rocket Plume Simulation at Mach Numbers 2 through 5." AEDC-TR-68-278 (AD848311), February 1969.

2. Test Facilities Handbook (Eighth Edition). "Propulsion Wind Tunnel Facility, Vol. 5." Arnold Engineering Development Center, December 1969 (AD863646).

# APPENDIXES

I. ILLUSTRATIONS

II. TABLES

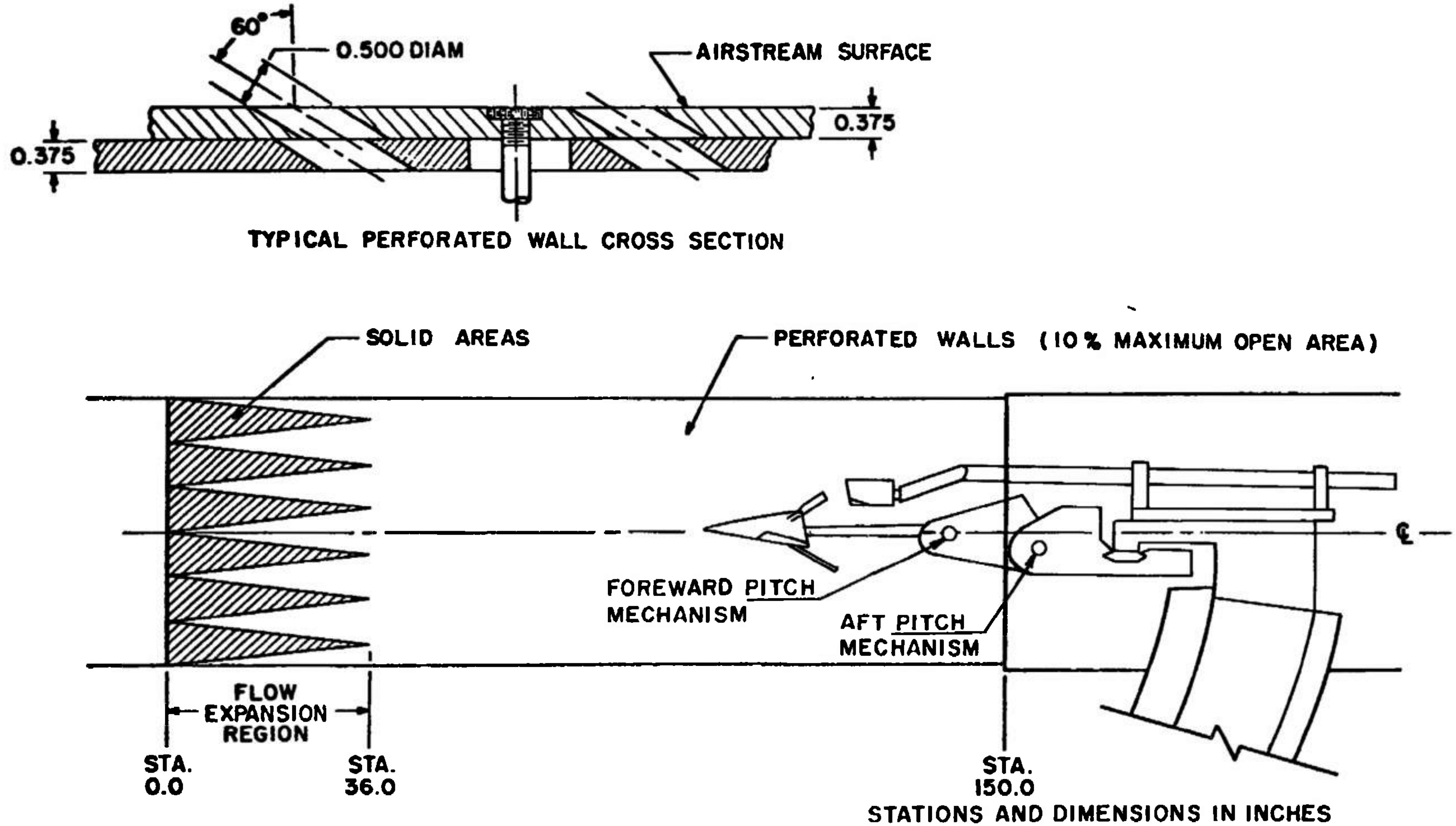
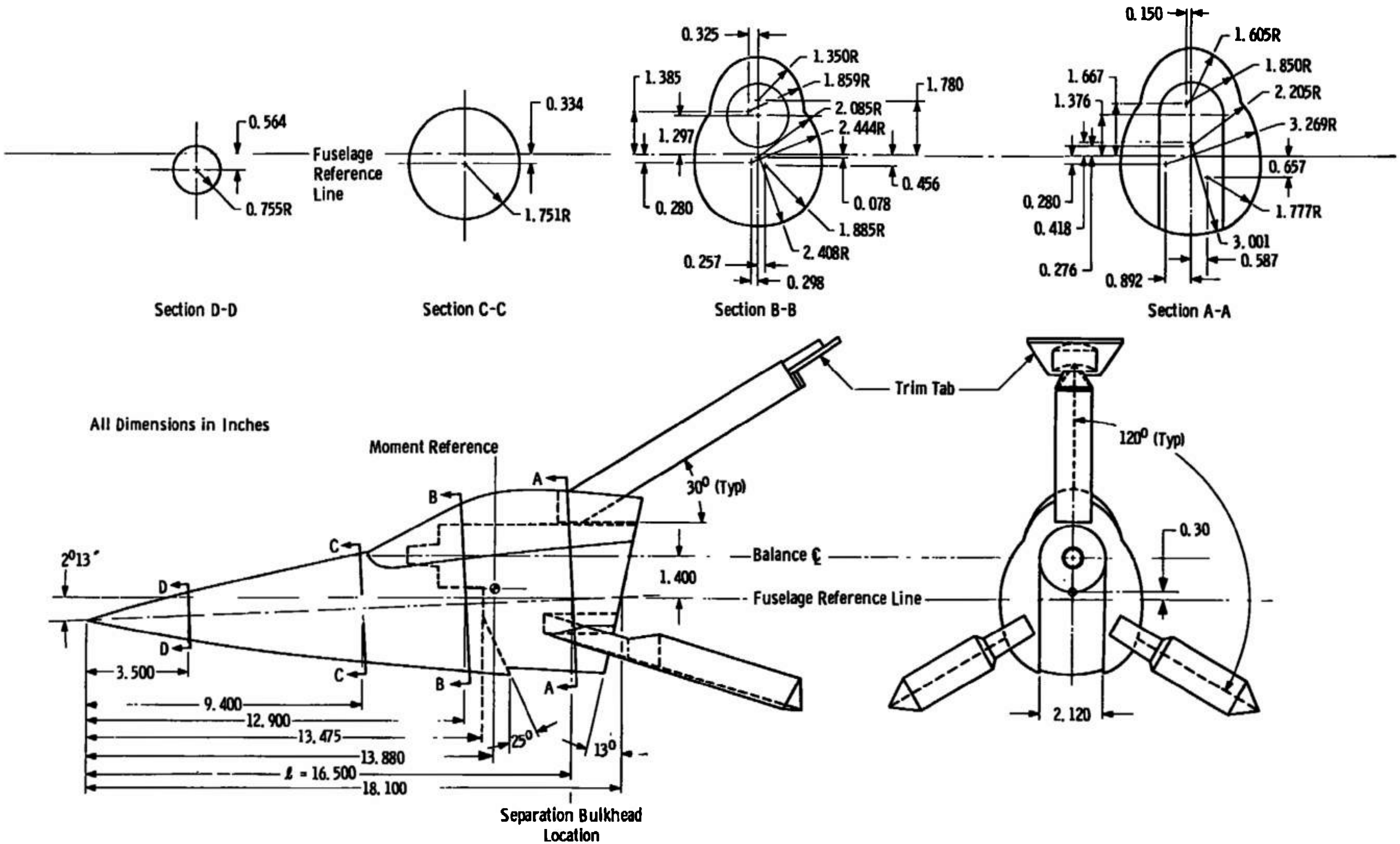


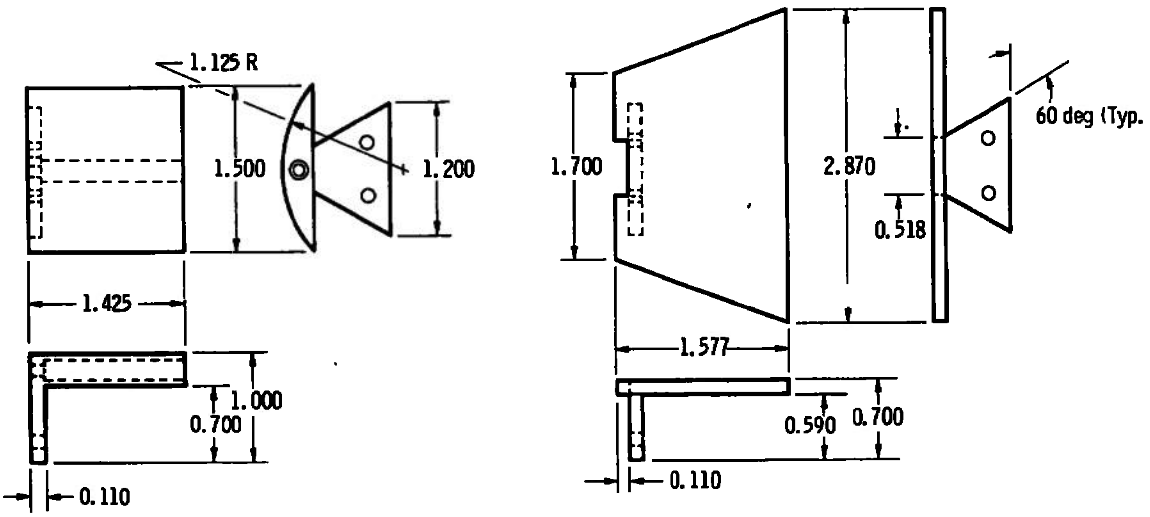

Fig. 1 Schematic of Model in Test Section



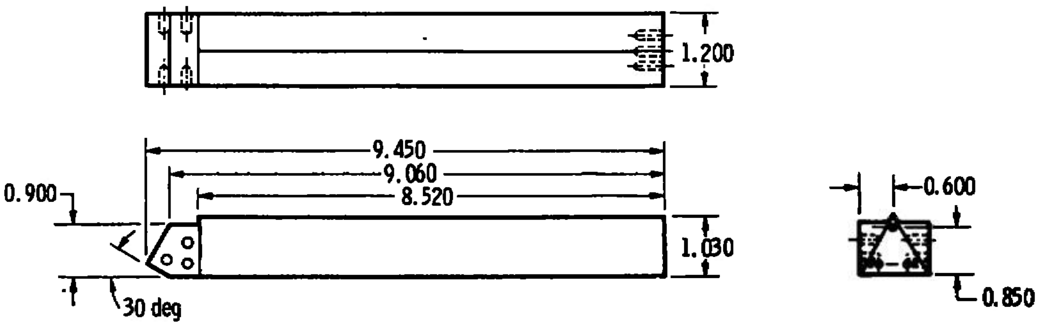

a. Capsule Details

Fig. 2 Model Details

All Dimensions in Inches

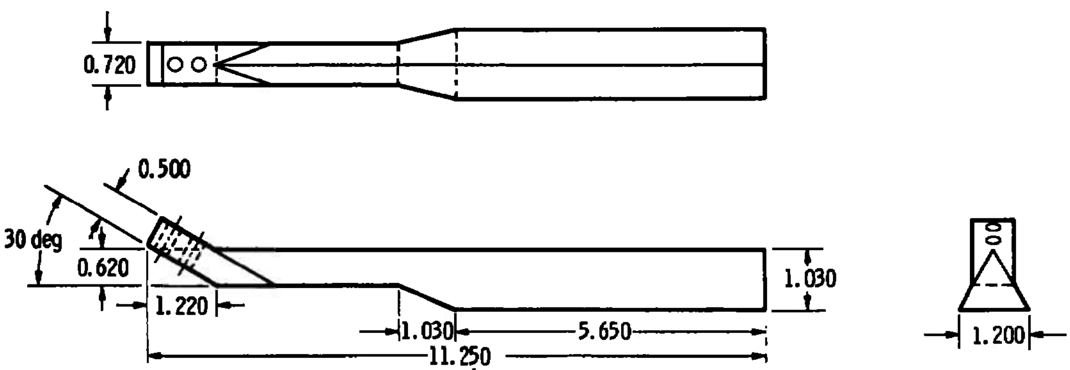



**b. Trim Tab Details**




Upper Boom

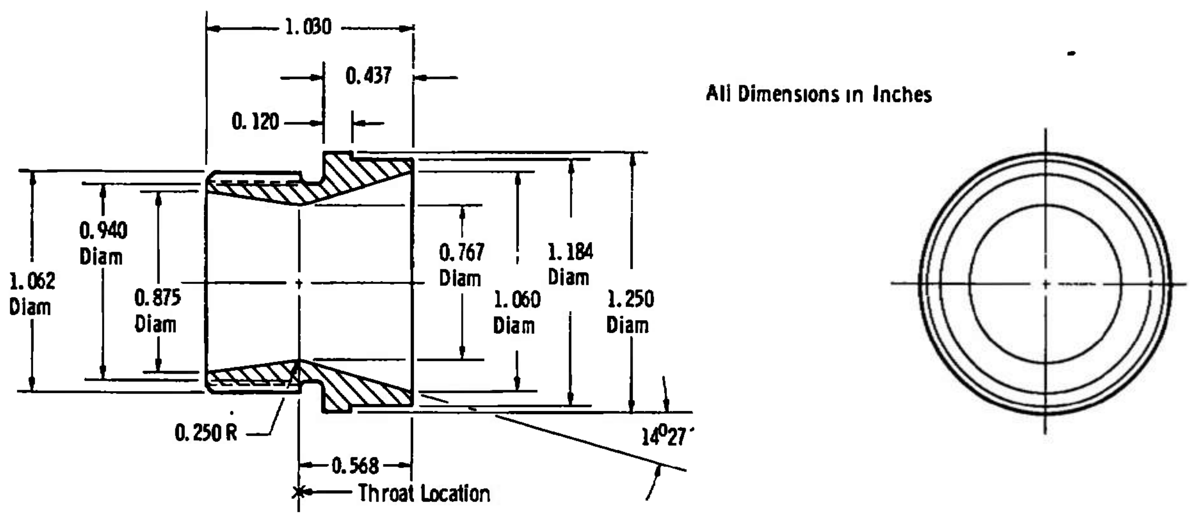
All Dimensions in Inches



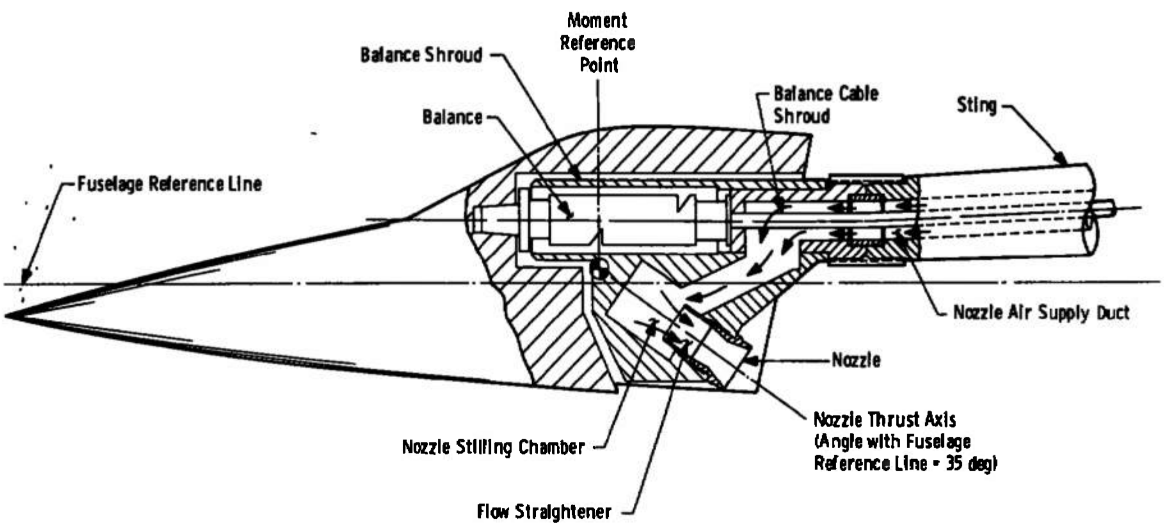

Lower Boom (2 Required)

**c. Trailing Boom Details**

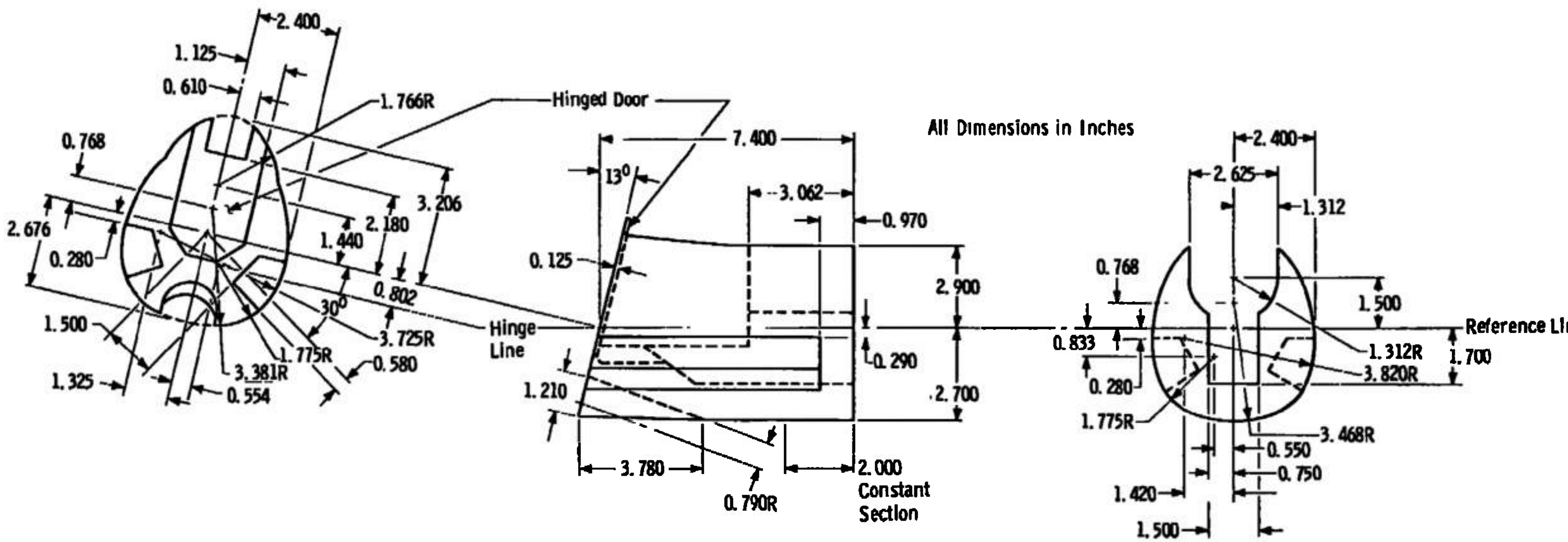
**Fig. 2 Continued**




d. Nozzle Details
Fig. 2 Continued

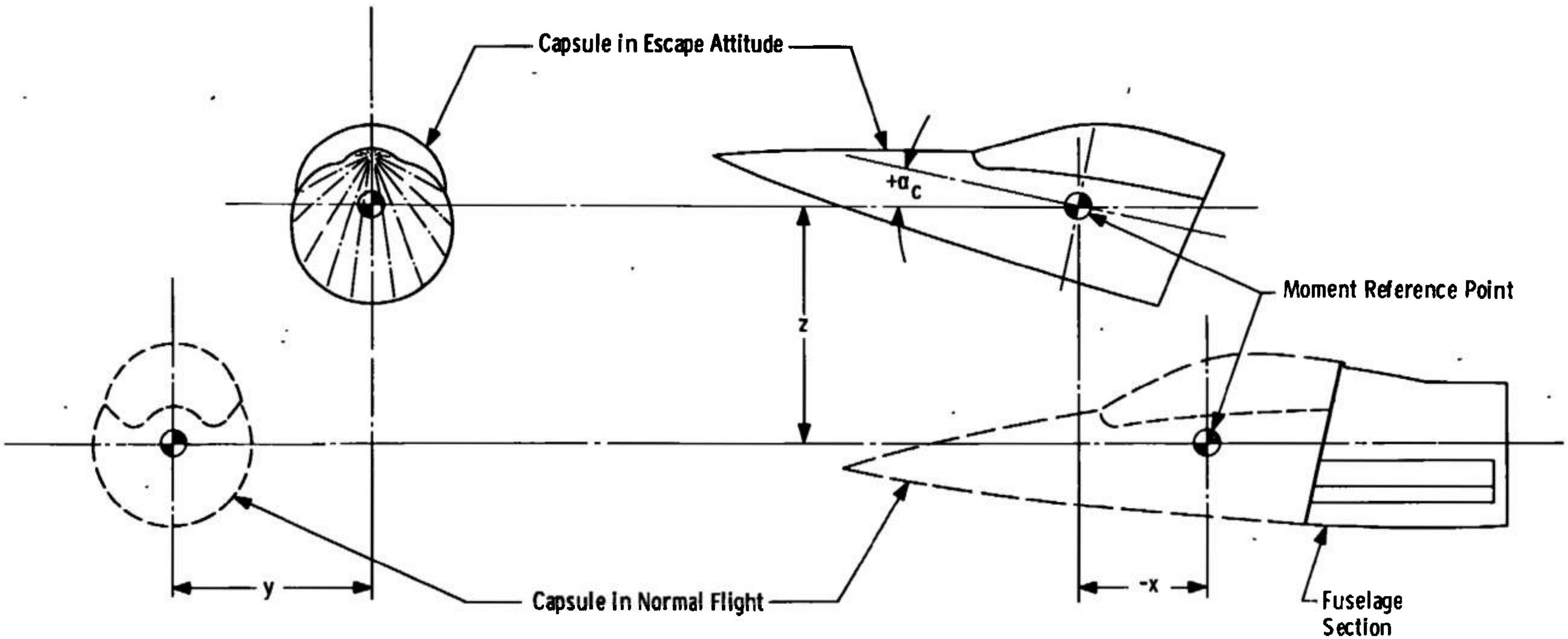



e. Capsule Installation Sketch
Fig. 2 Continued

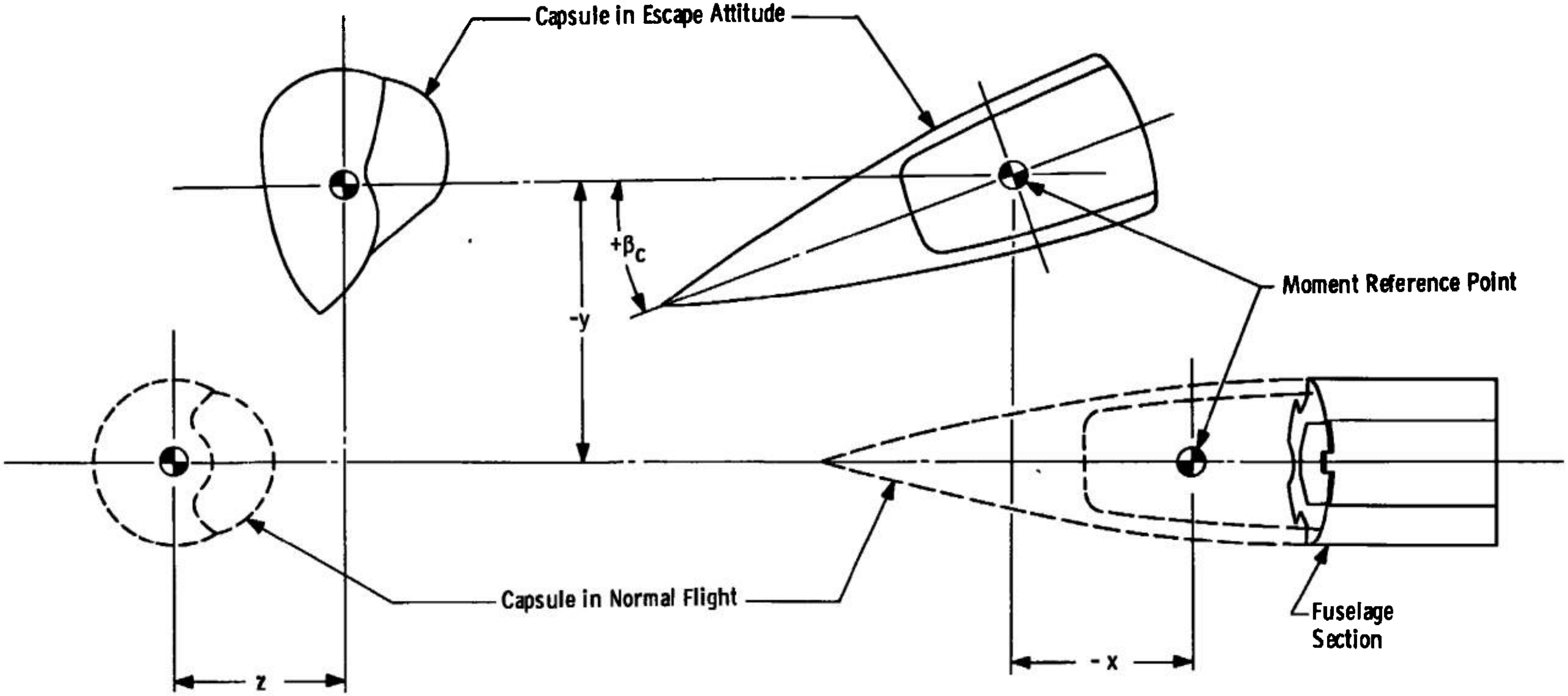



**f. Fuselage Details**

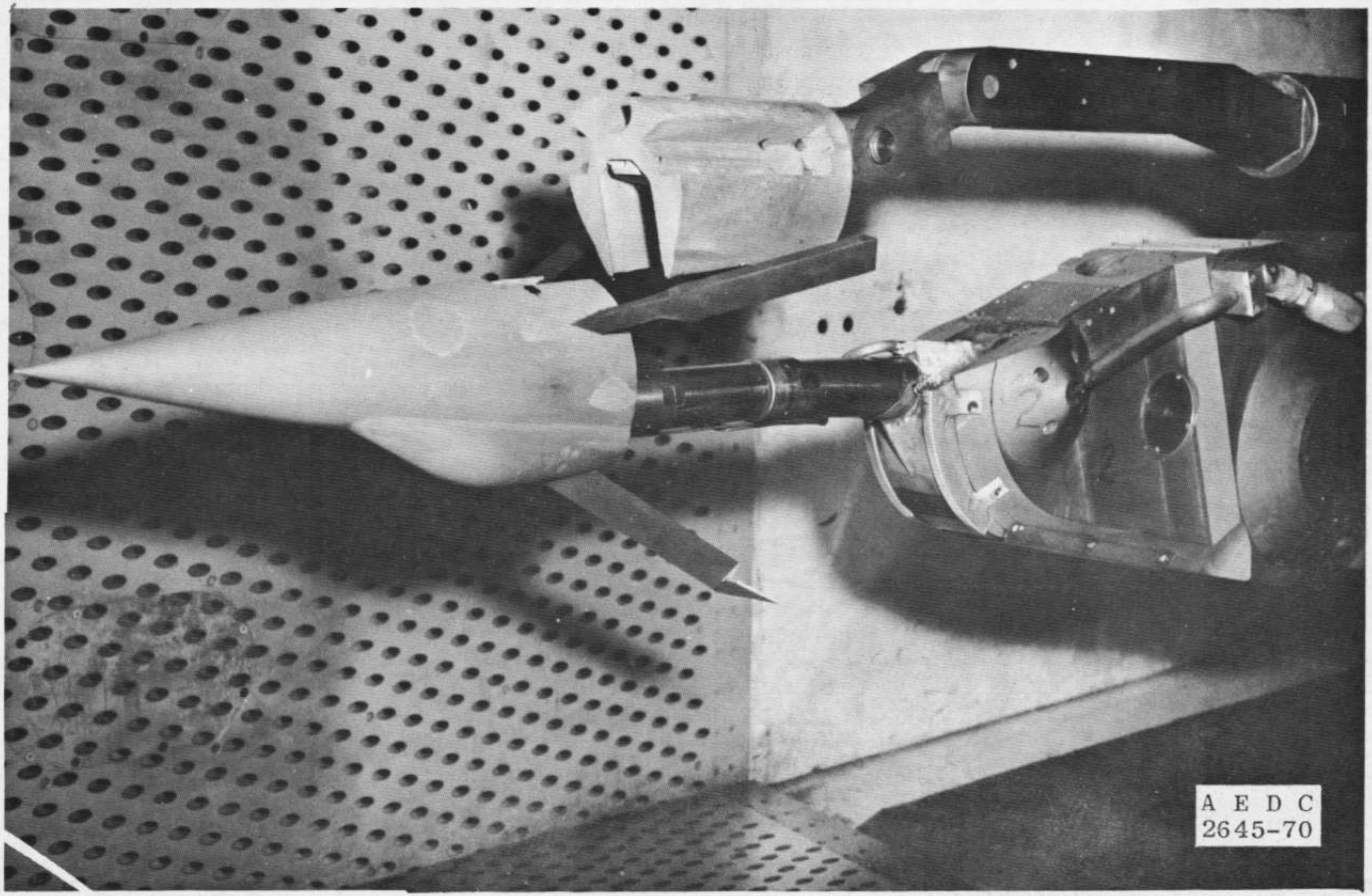
**Fig. 2 Concluded**



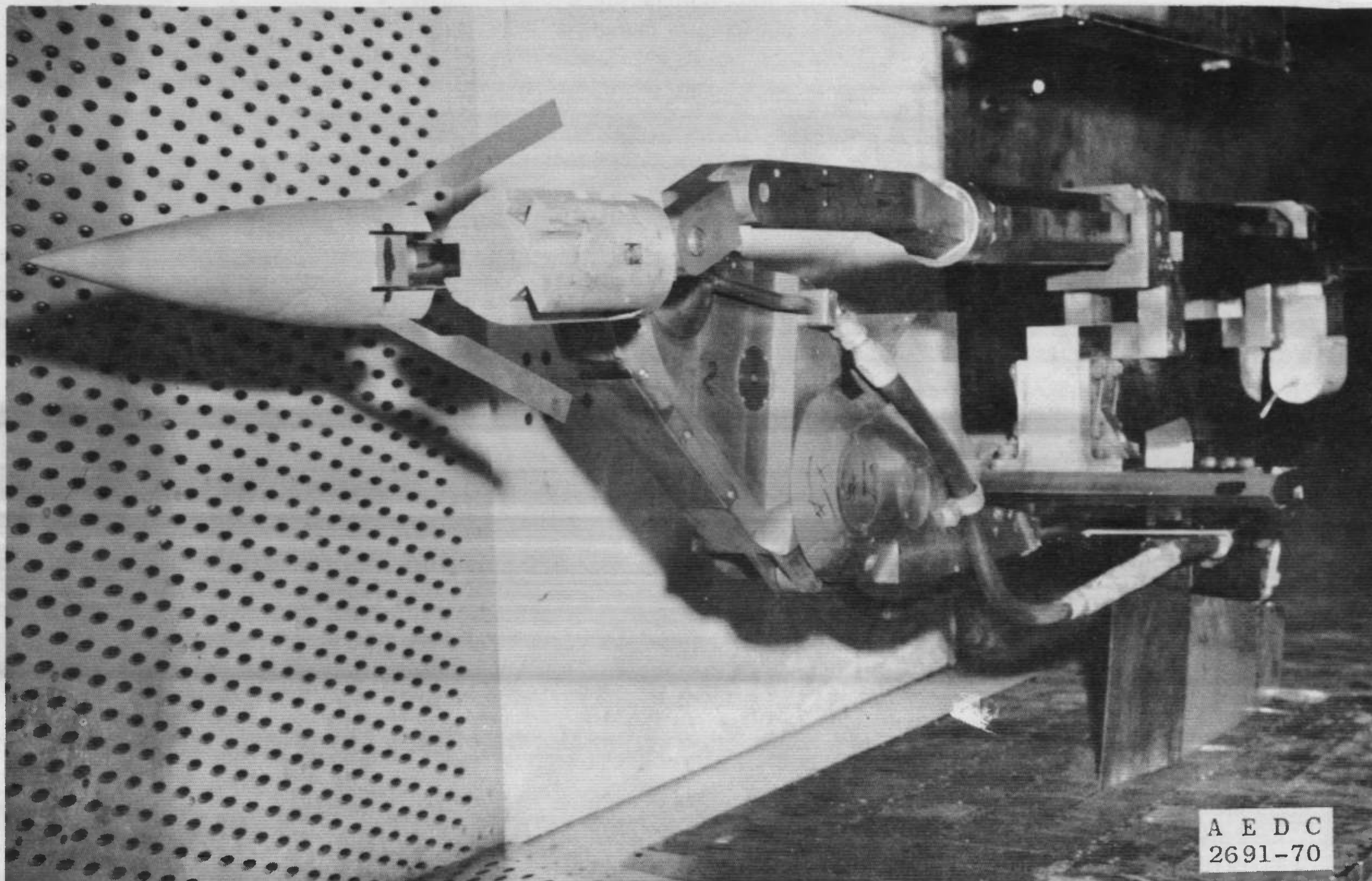

a. Pitch Plane
Fig. 3 Capsule and Fuselage Proximity Details




b. Yaw Plane
Fig. 3 Concluded




a. Model in Pitch Plane
Fig. 4 Installation Photographs




b. Model in Yaw Plane
Fig. 4 Concluded

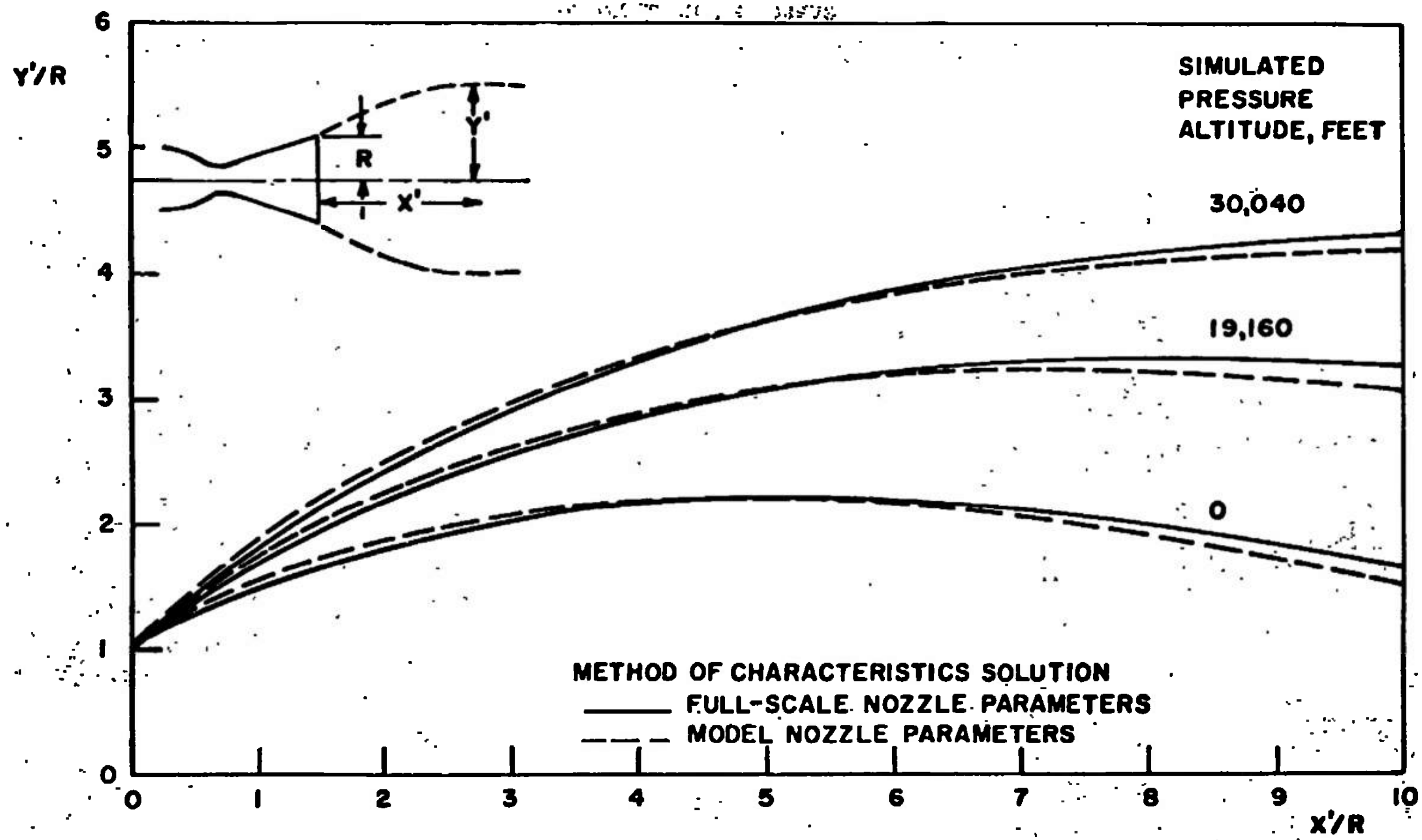
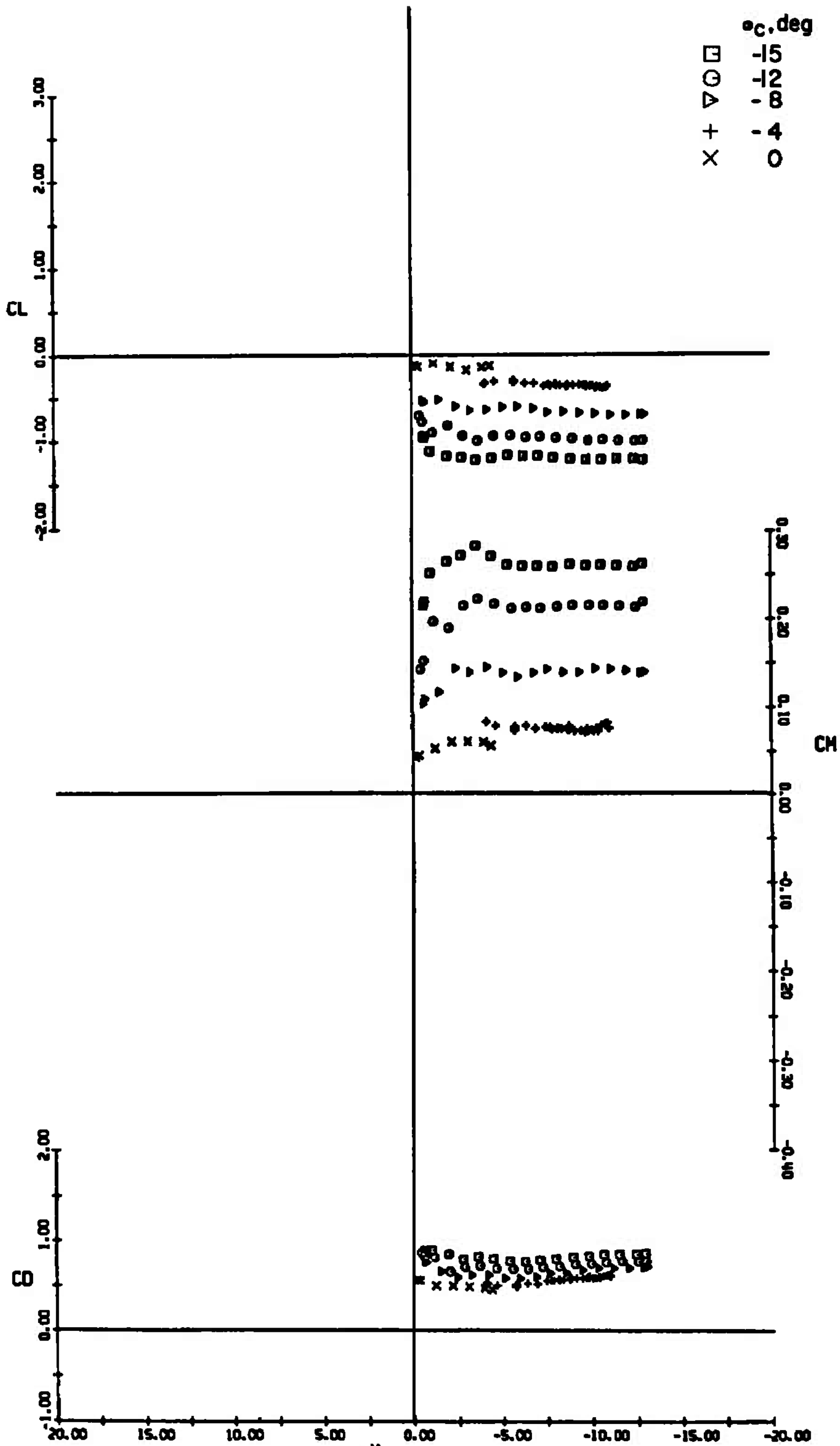
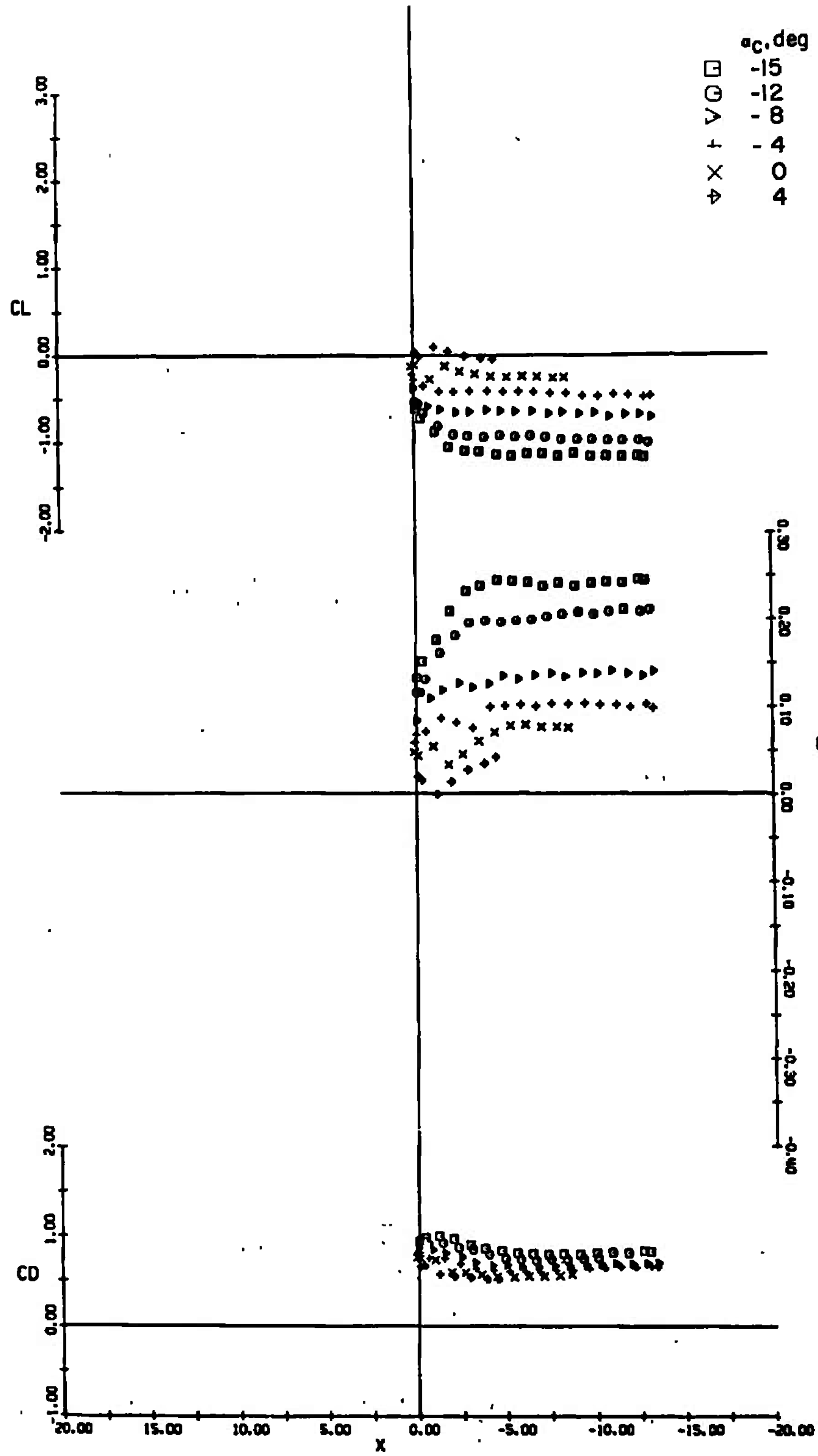



Fig. 5 Comparison of Full-Scale and Model Plume Shapes

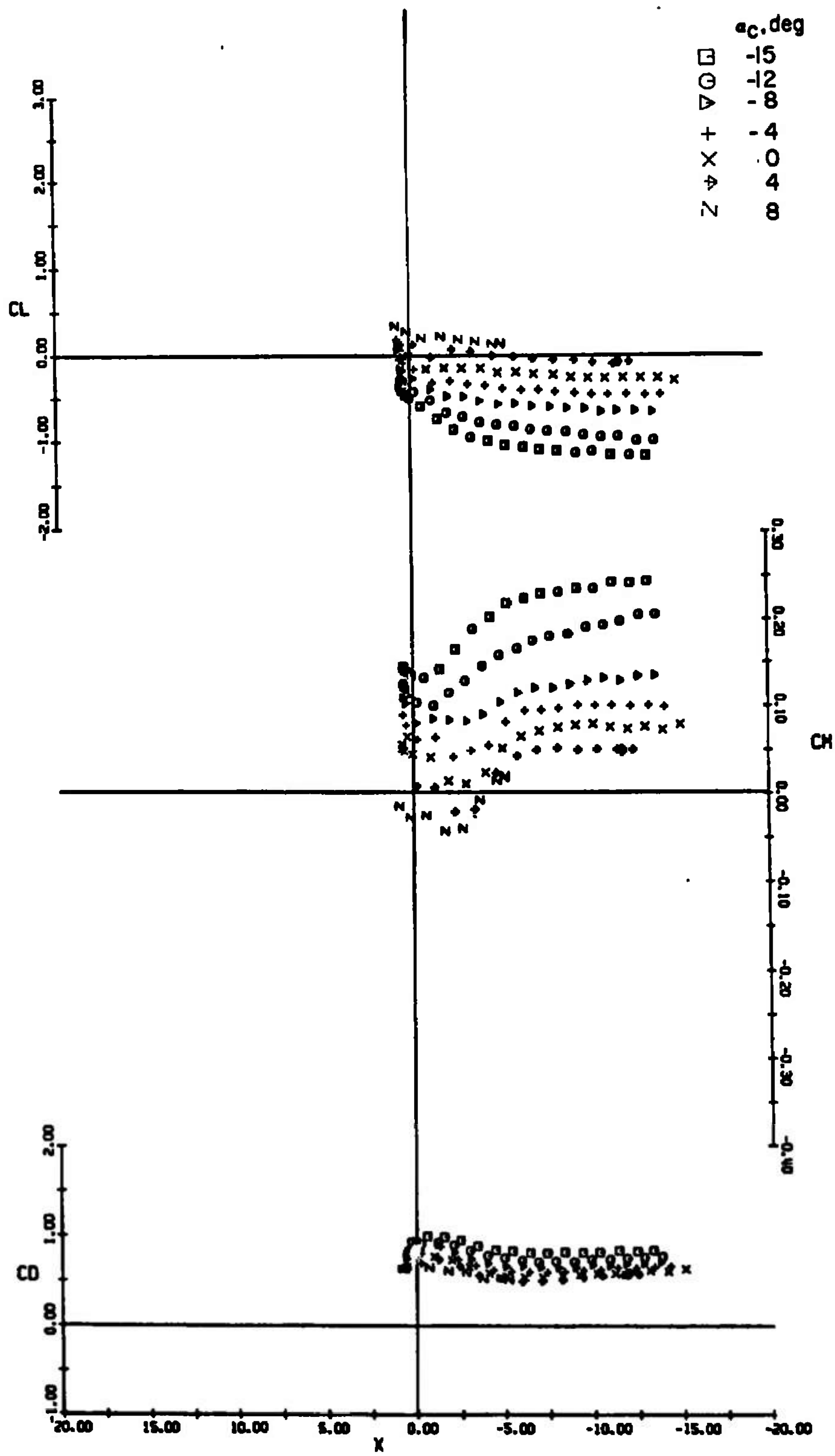



a. Z = 0 in.

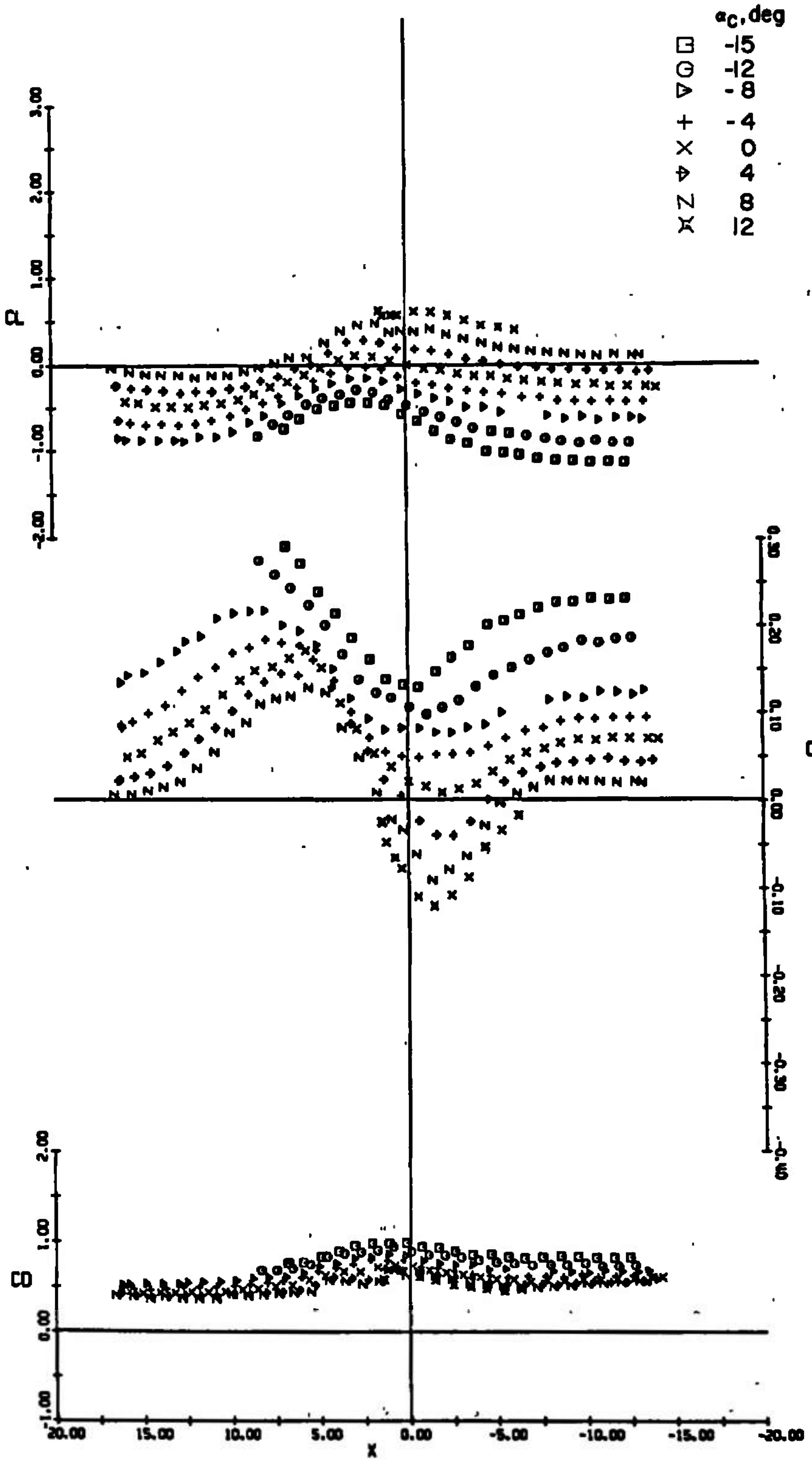
Fig. 6 Lift, Pitching-Moment, and Drag Characteristics of the Capsule at Various Angles of Attack, Jet Off, Y = 0, $M_\infty$ = 0.3




b. Z = 2 in.
Fig. 6 Continued

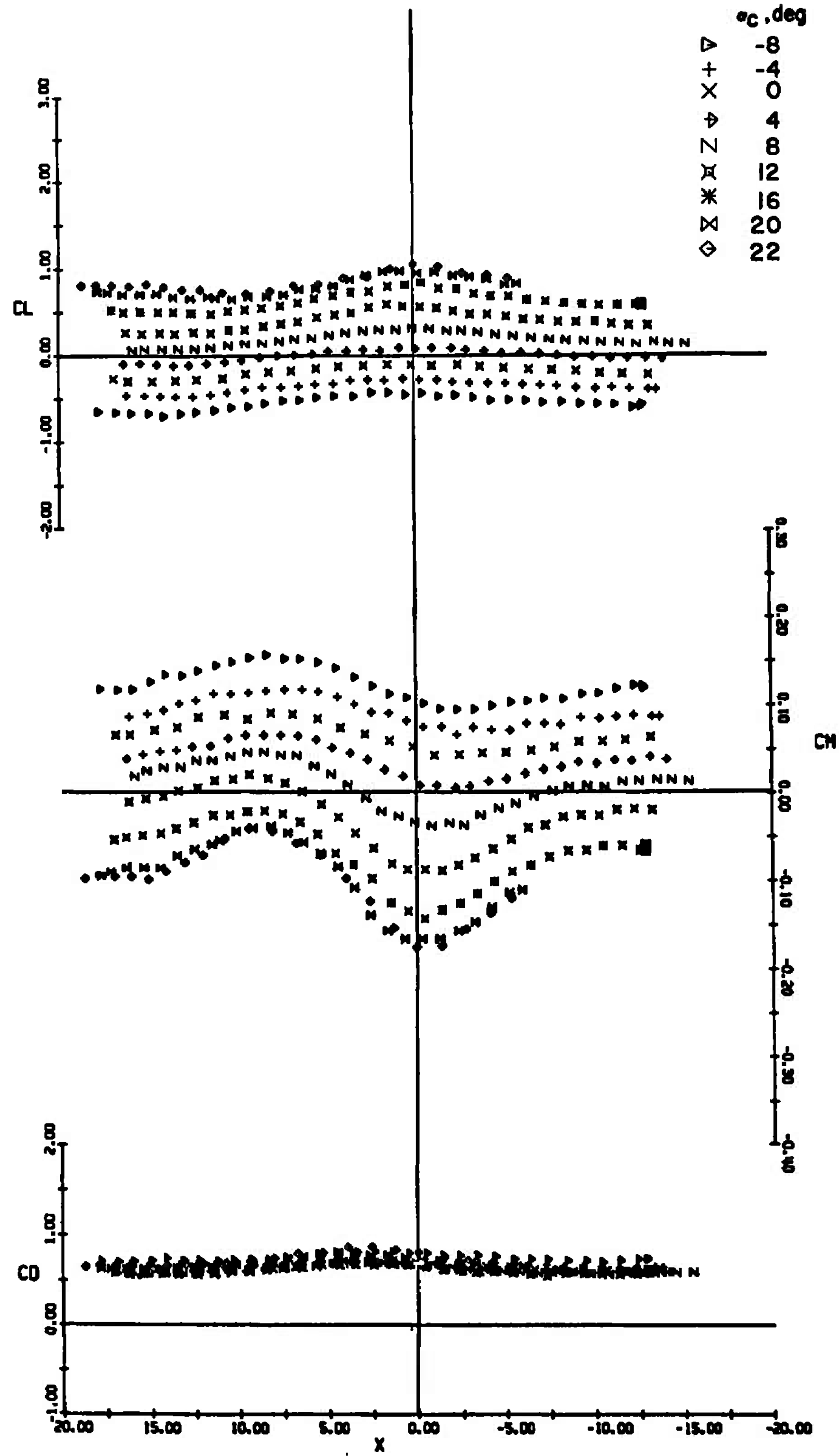



c. Z = 4 in.
Fig. 6 Continued

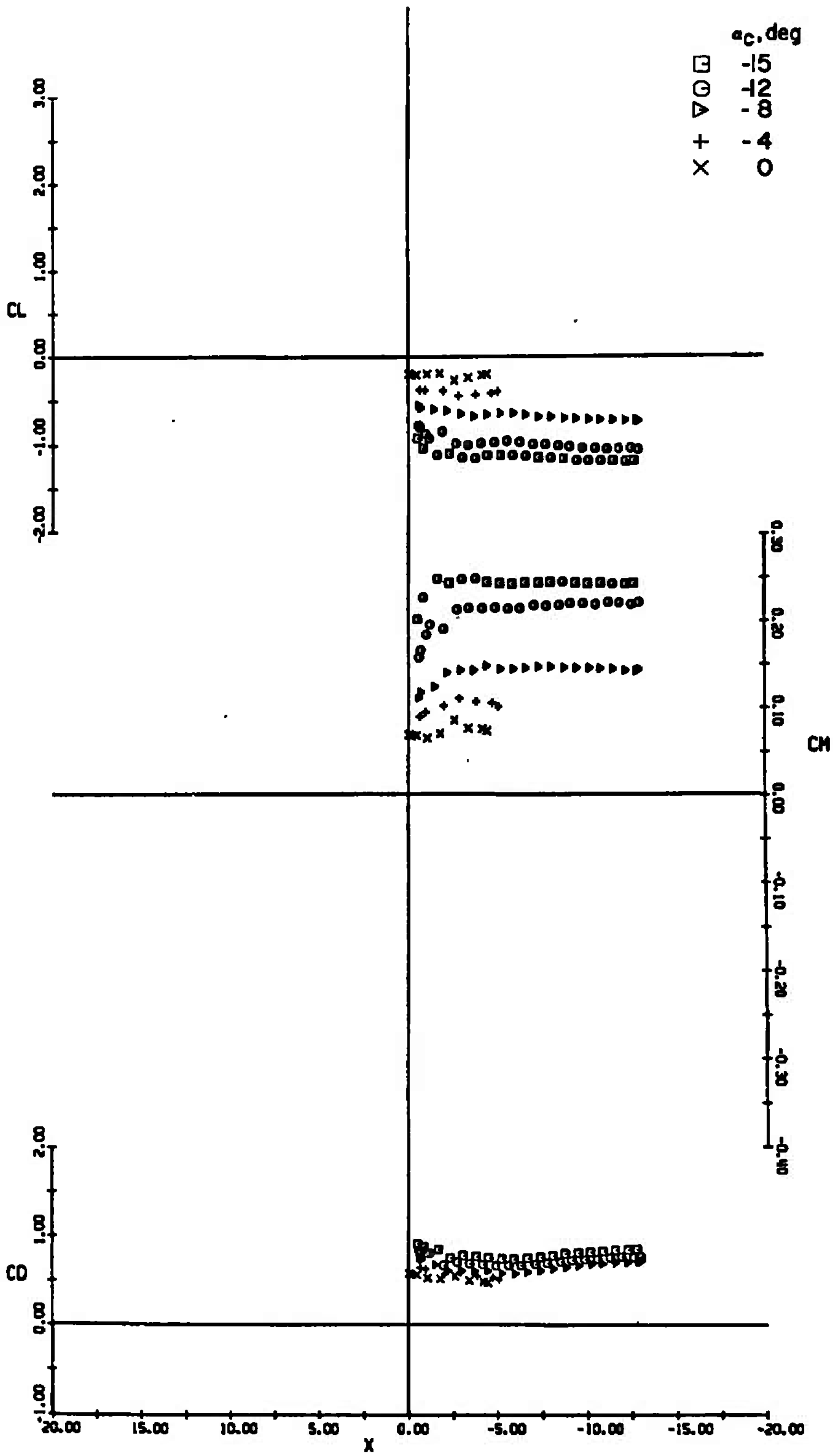



d. Z = 6 in.

Fig. 6 Continued

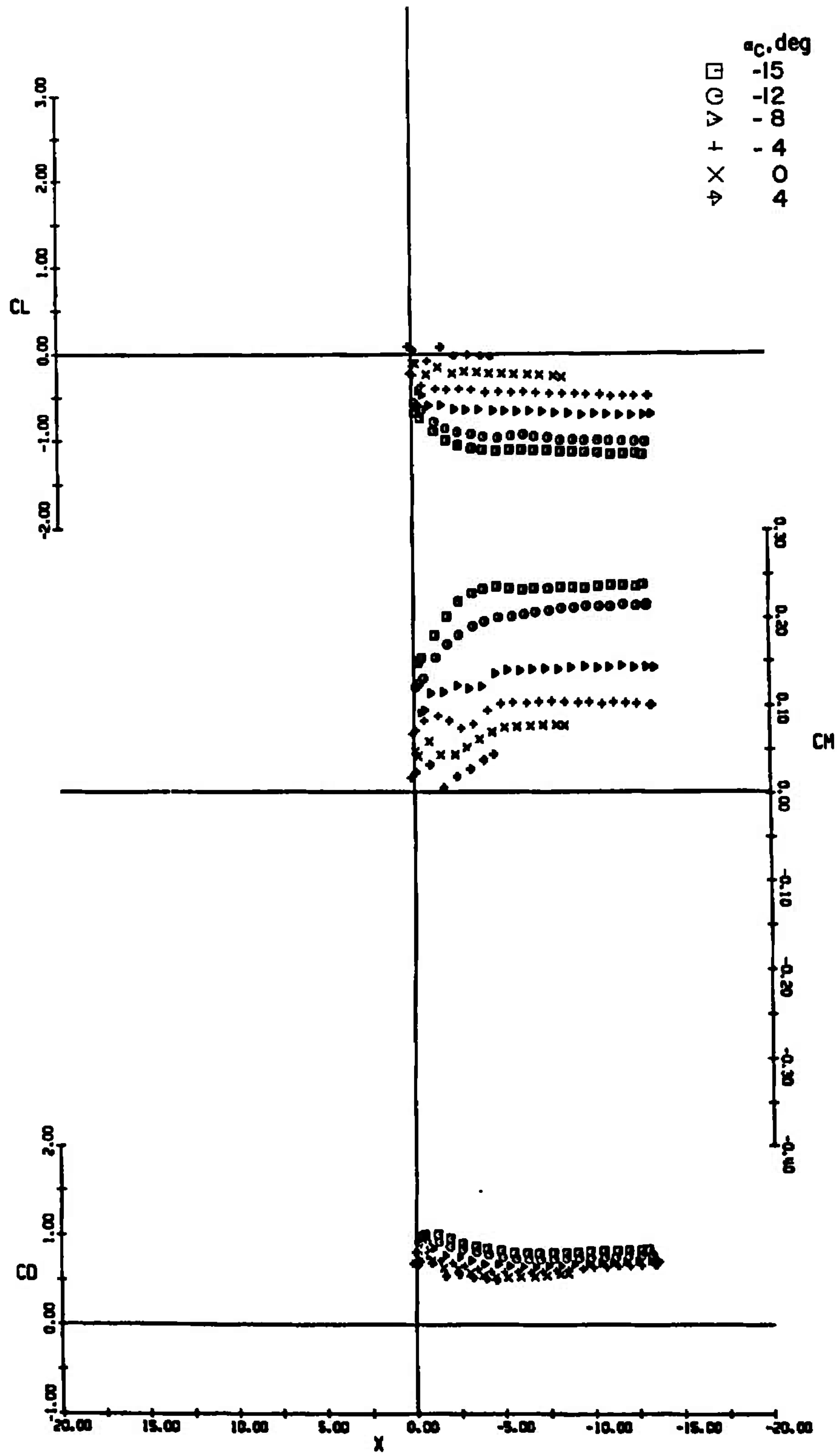



e. Z = 10 in.
Fig. 6 Concluded

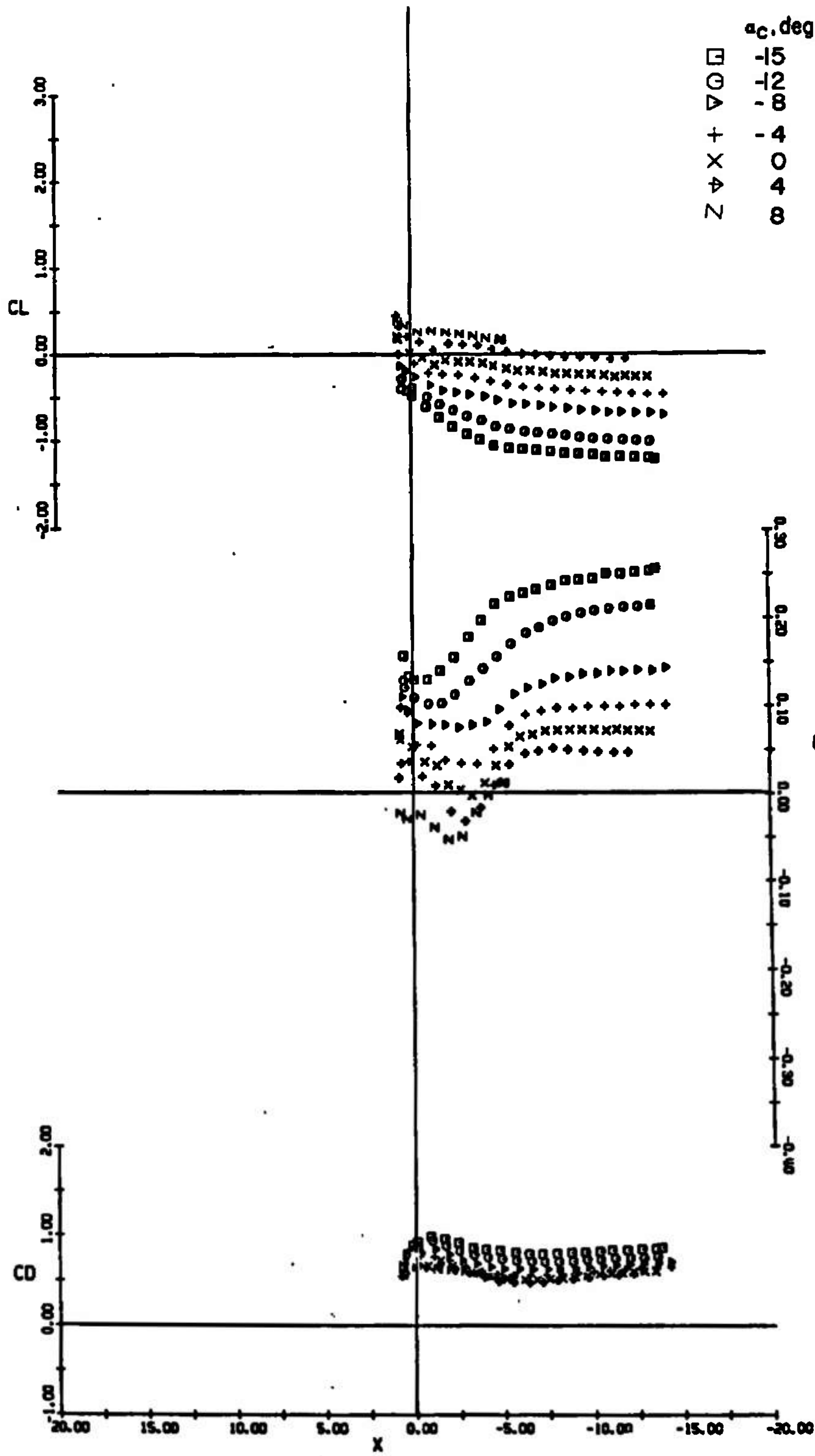



a. Z = 0 in.

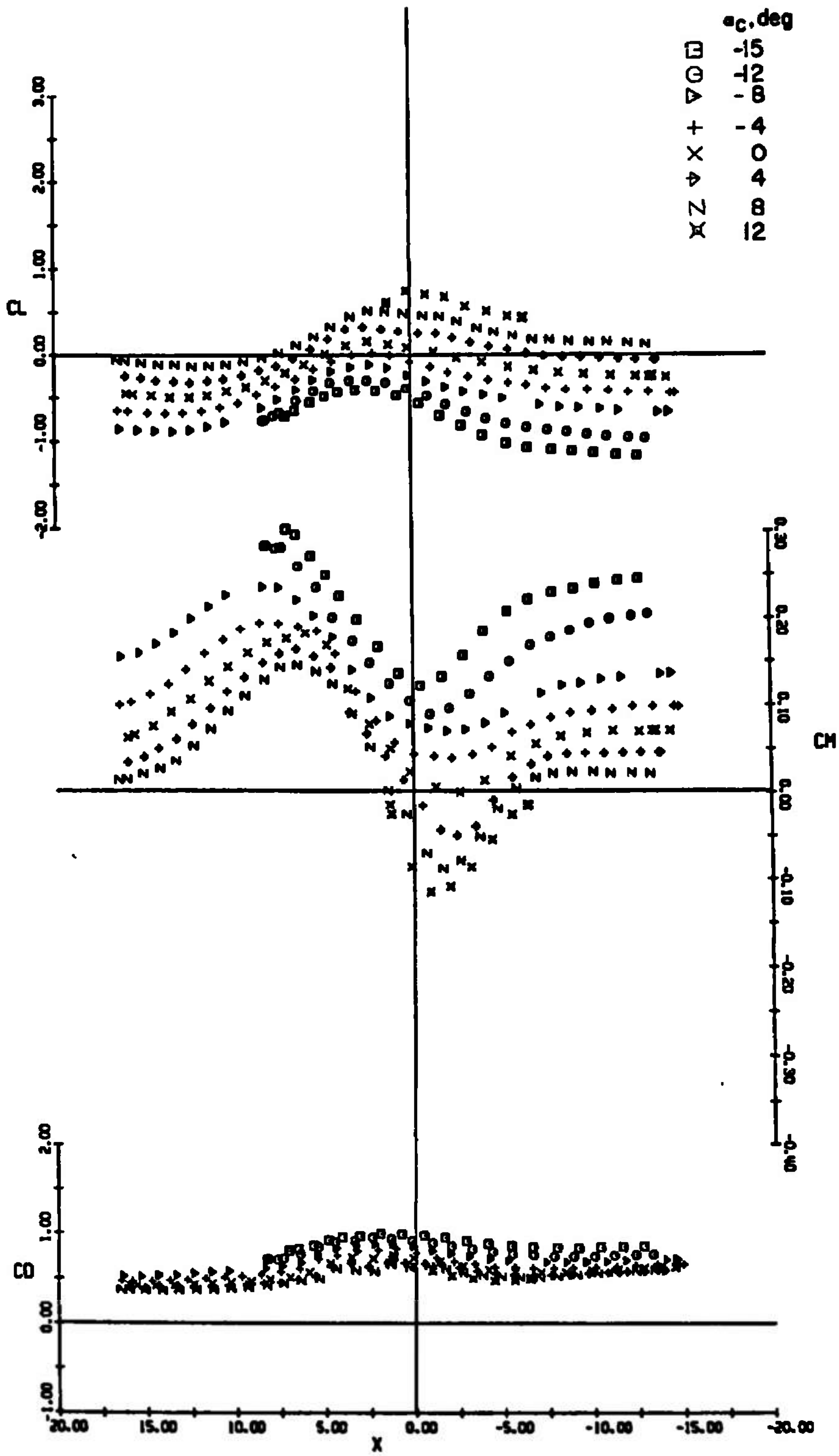
Fig. 7 Lift, Pitching-Moment, and Drag Characteristics of the Capsule at Various Angles of Attack, Jet Off, Y = 0, $M_\infty$ = 0.6



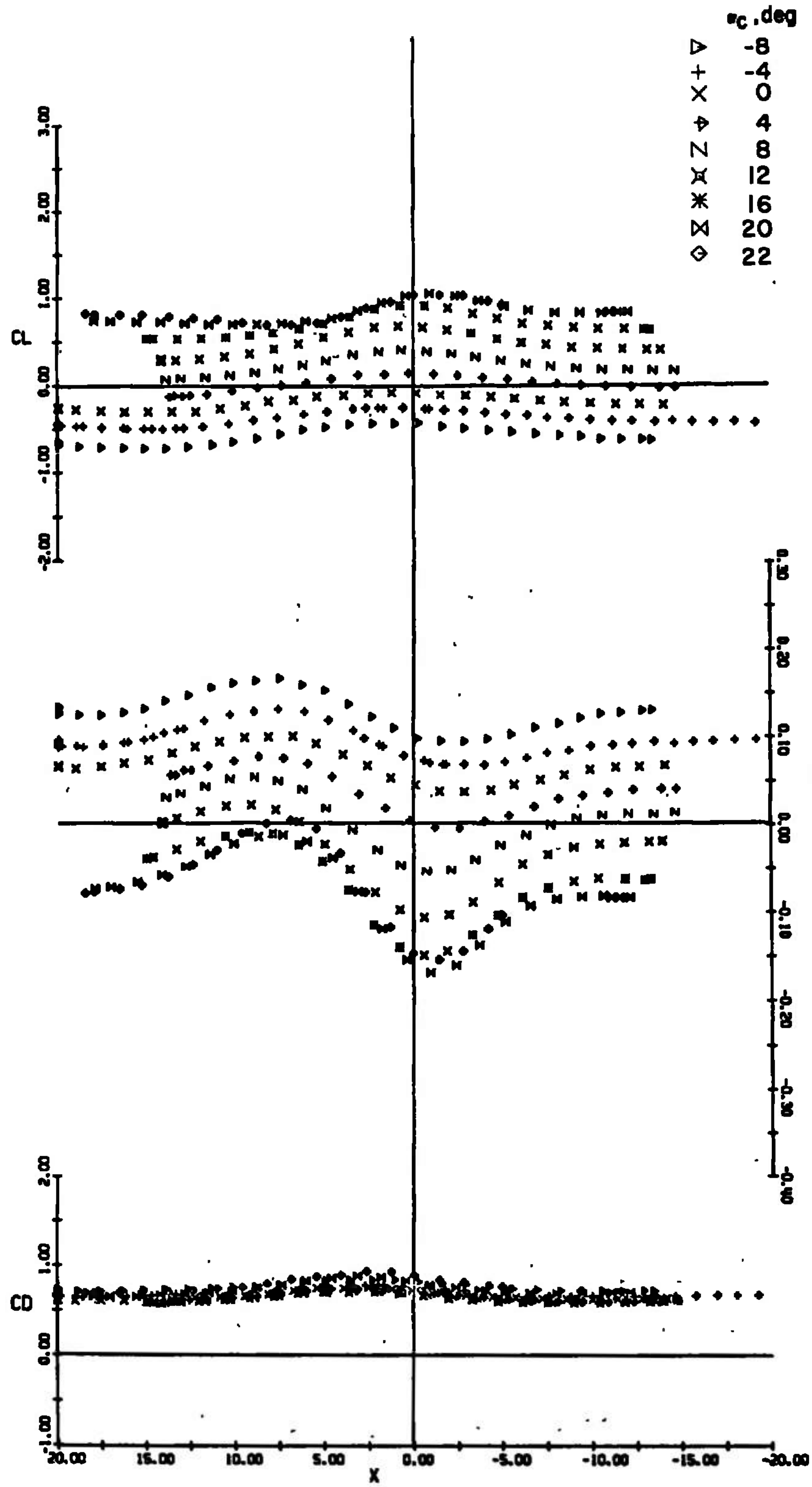

b. Z = 2 in.
Fig. 7 Continued



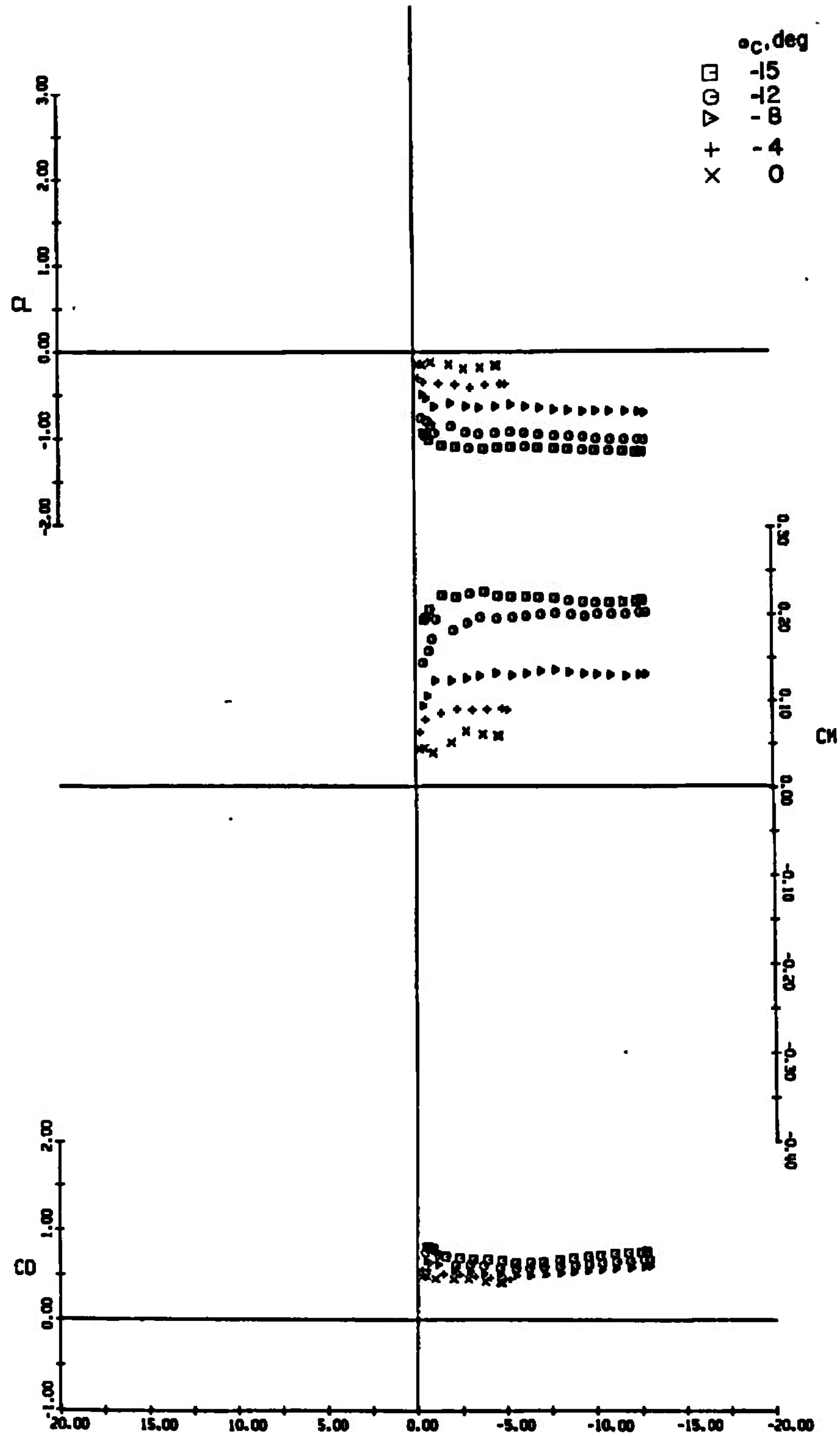

c. Z = 4 in.
Fig. 7 Continued




d. Z = 6 in.
Fig. 7 Continued

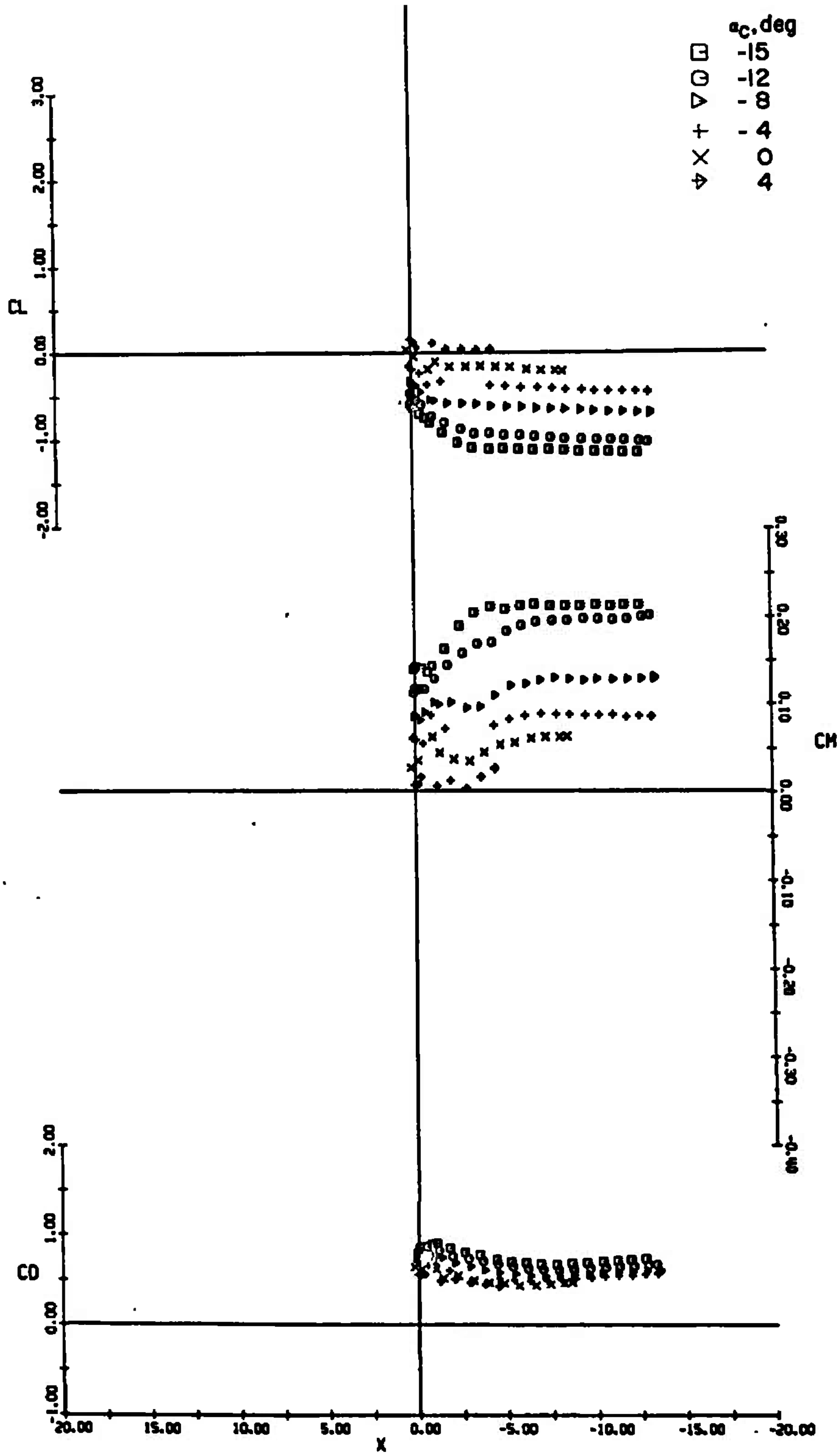



e. Z = .10 in.
Fig. 7 Concluded

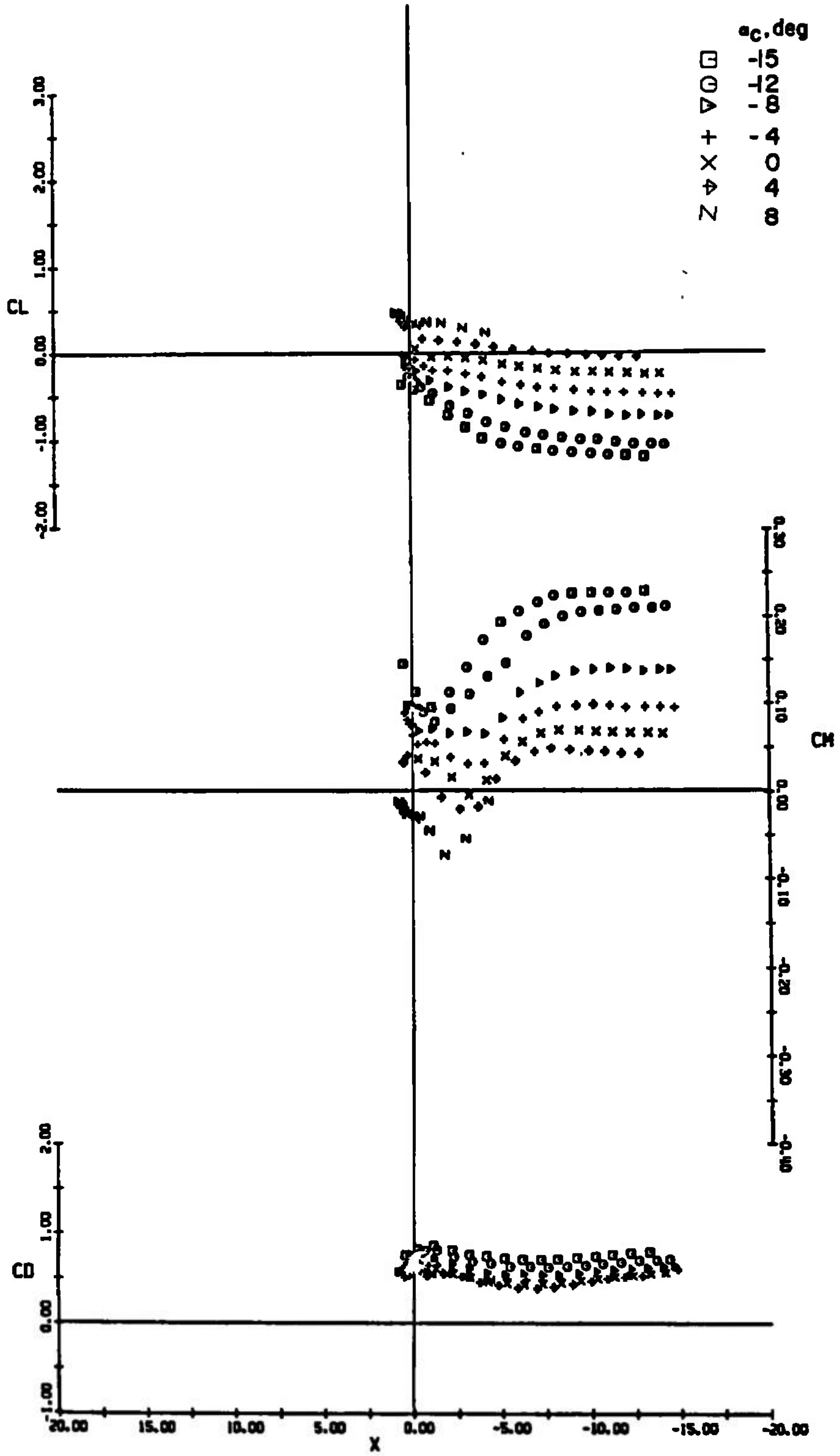



a. Z = 0 in.

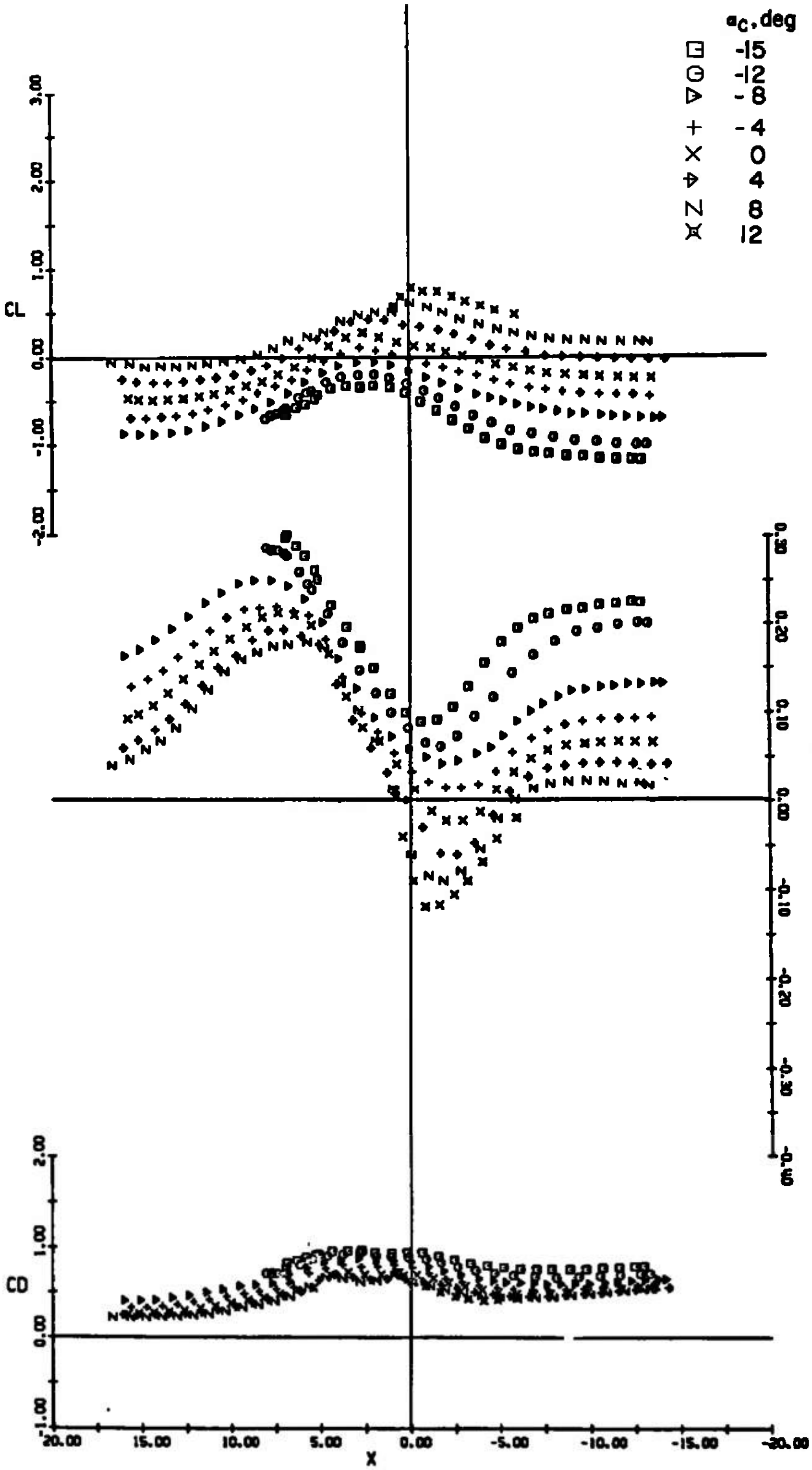
Fig. 8 Lift, Pitching-Moment, and Drag Characteristics of the Capsule at Various Angles of Attack, Jet Off, Y = 0, $M_\infty$ = 0.9



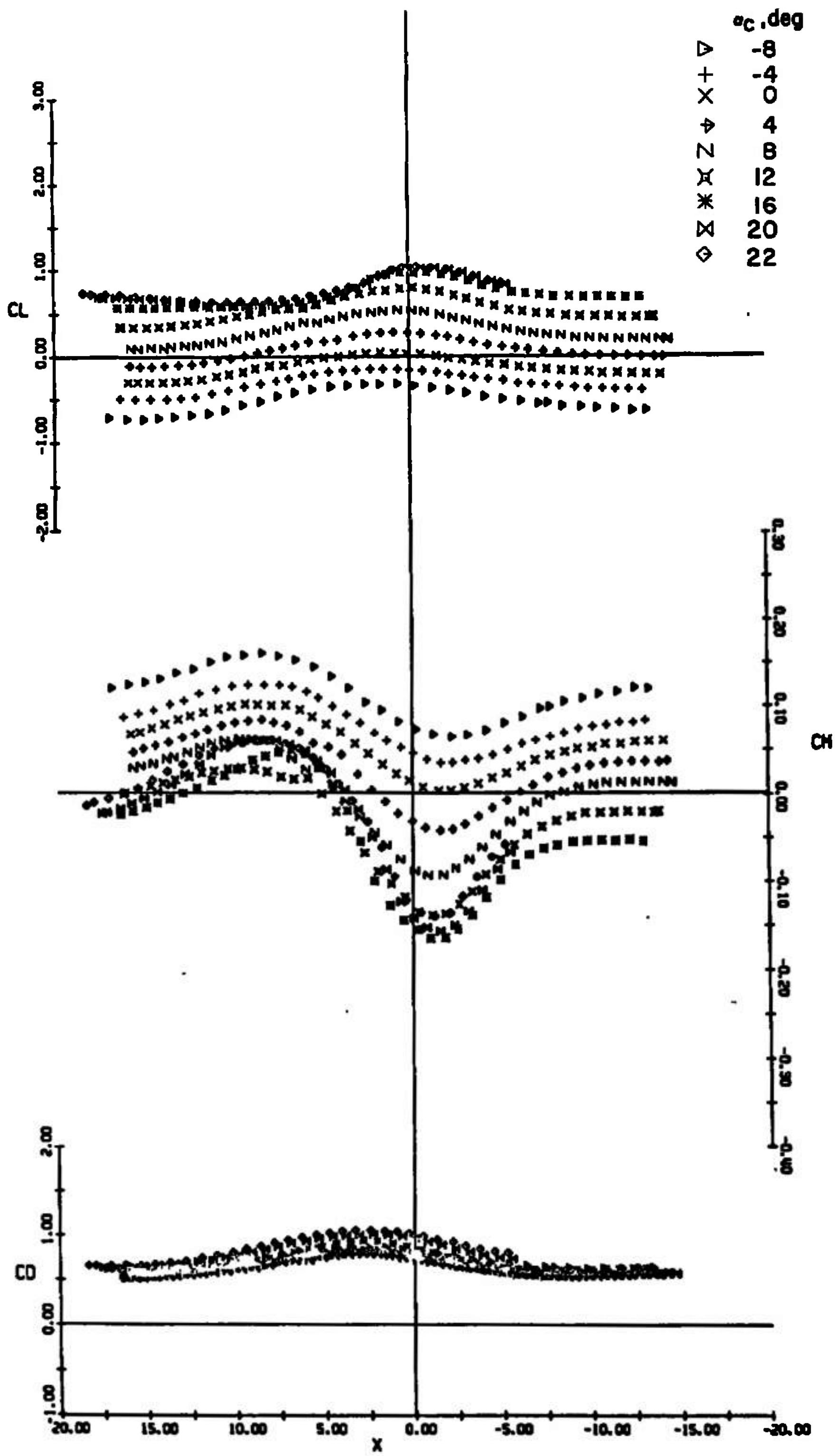

b. Z = 2 in.
Fig. 8 Continued



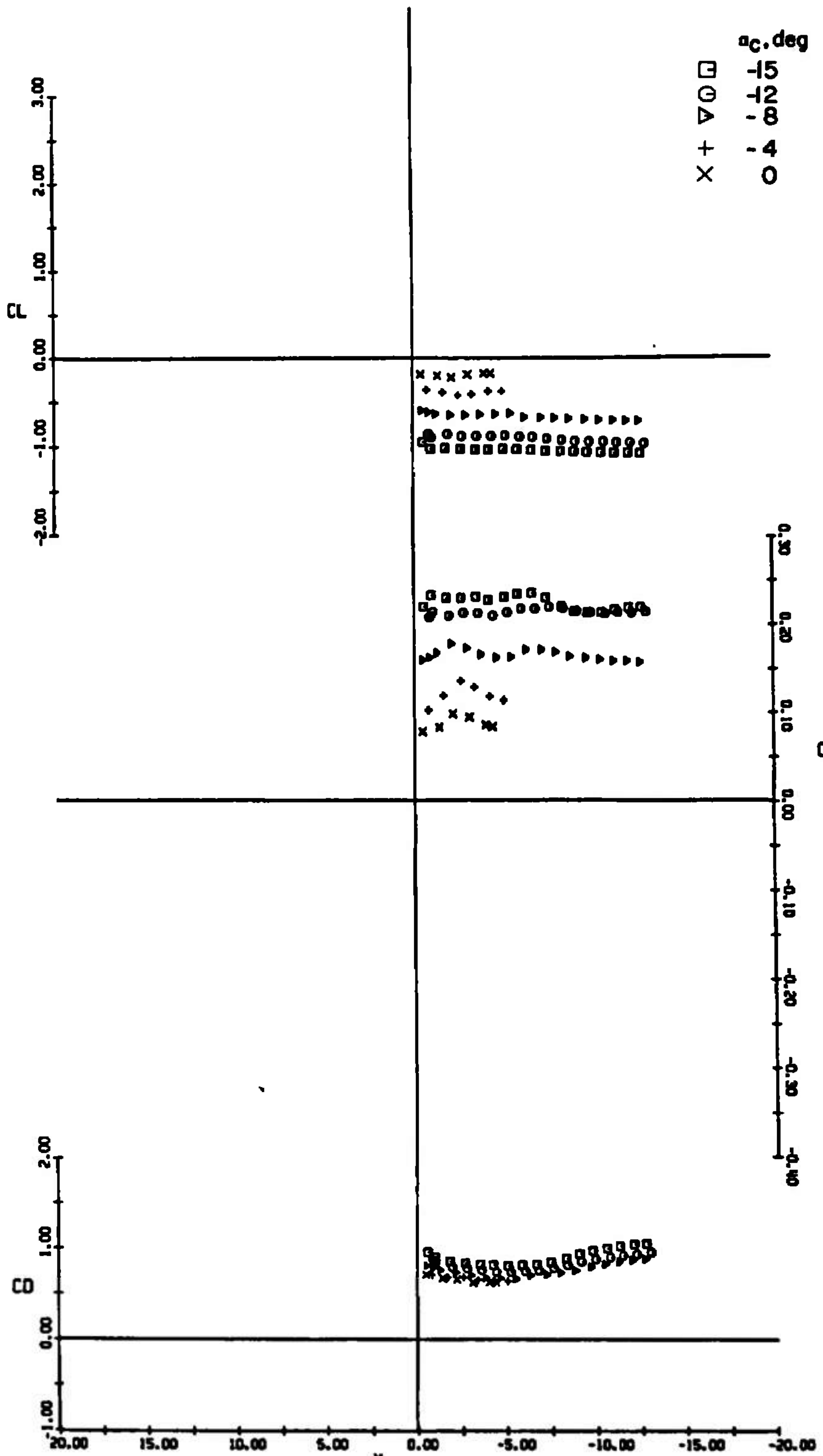

c. Z = 4 in.
Fig. 8 Continued




d. Z = 6 in.
Fig. 8 Continued

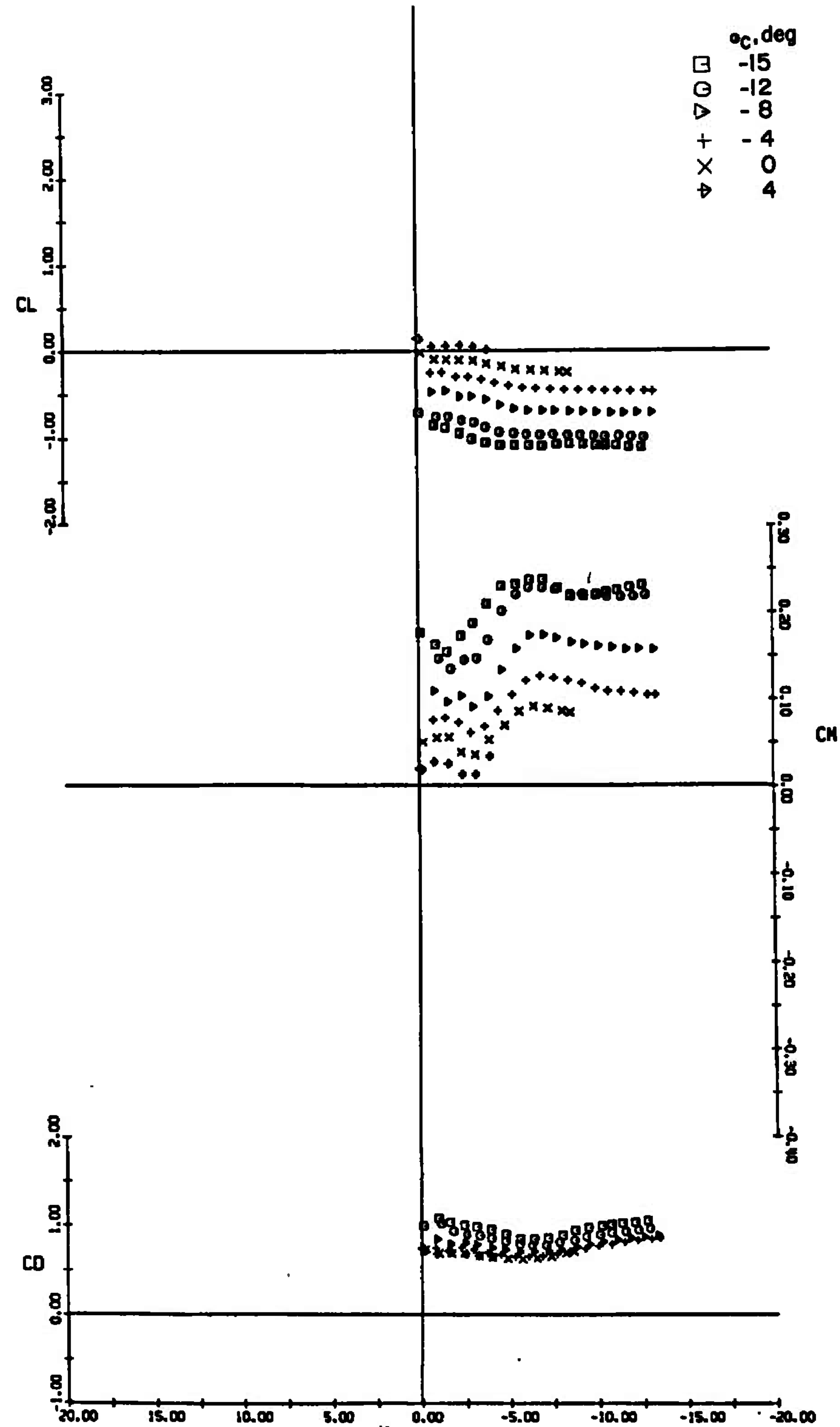



e. Z = 10 in.
Fig. 8 Concluded

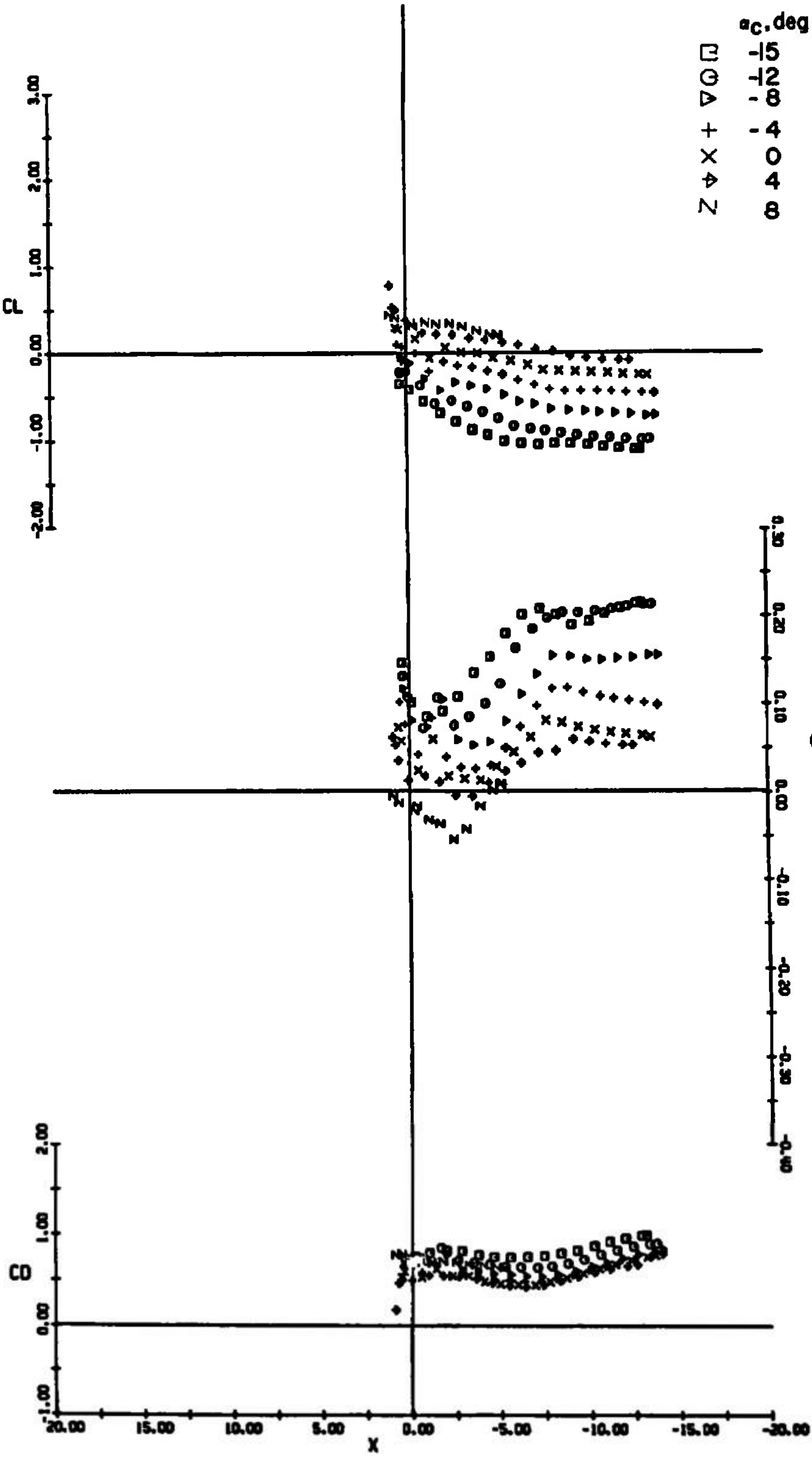



a. Z = 0 in.

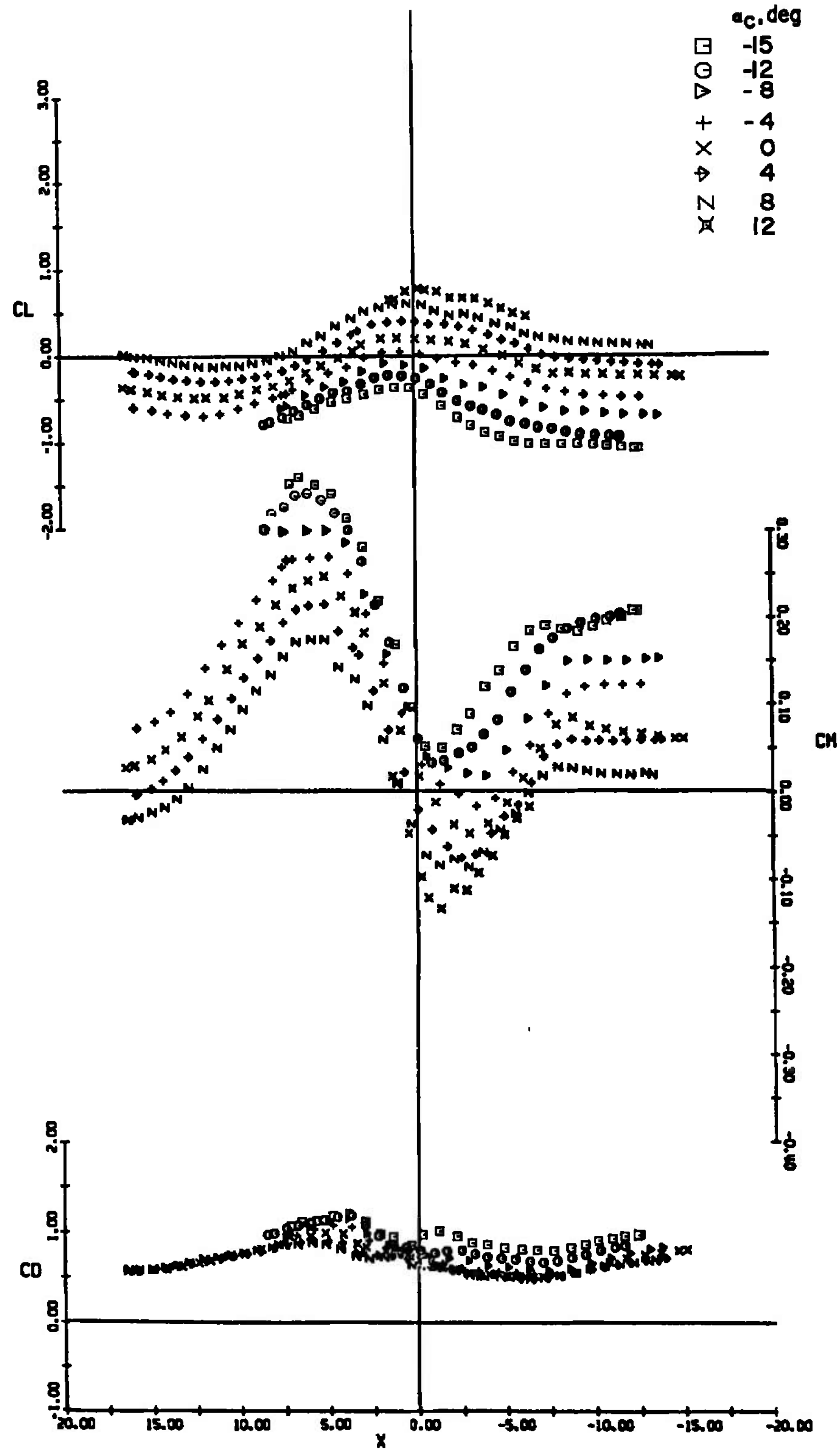
Fig. 9 Lift, Pitching-Moment, and Drag Characteristics of the Capsule at Various Angles of Attack, Jet Off, Y = 0, $M_\infty$ = 12



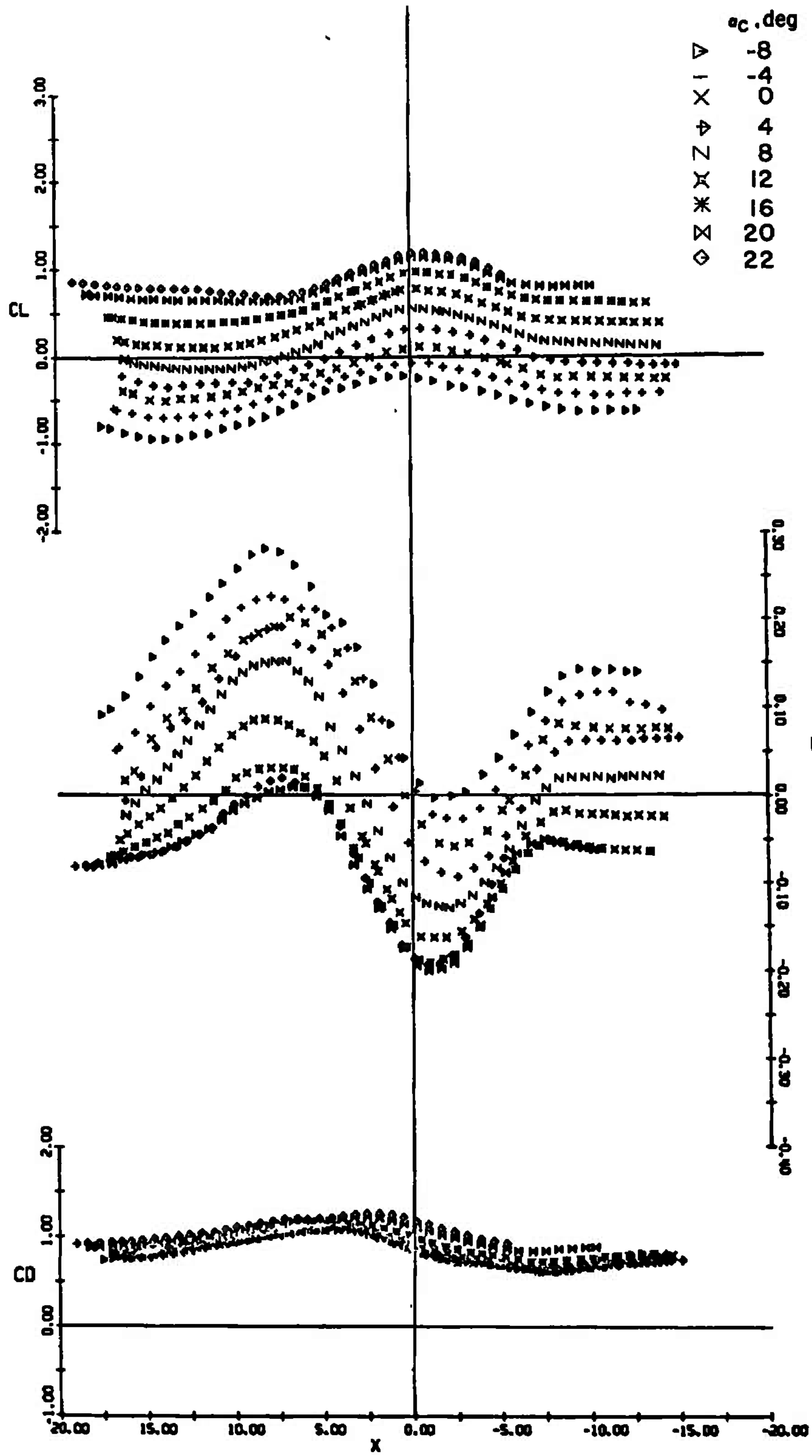

b. Z = 2 in.
Fig. 9 Continued



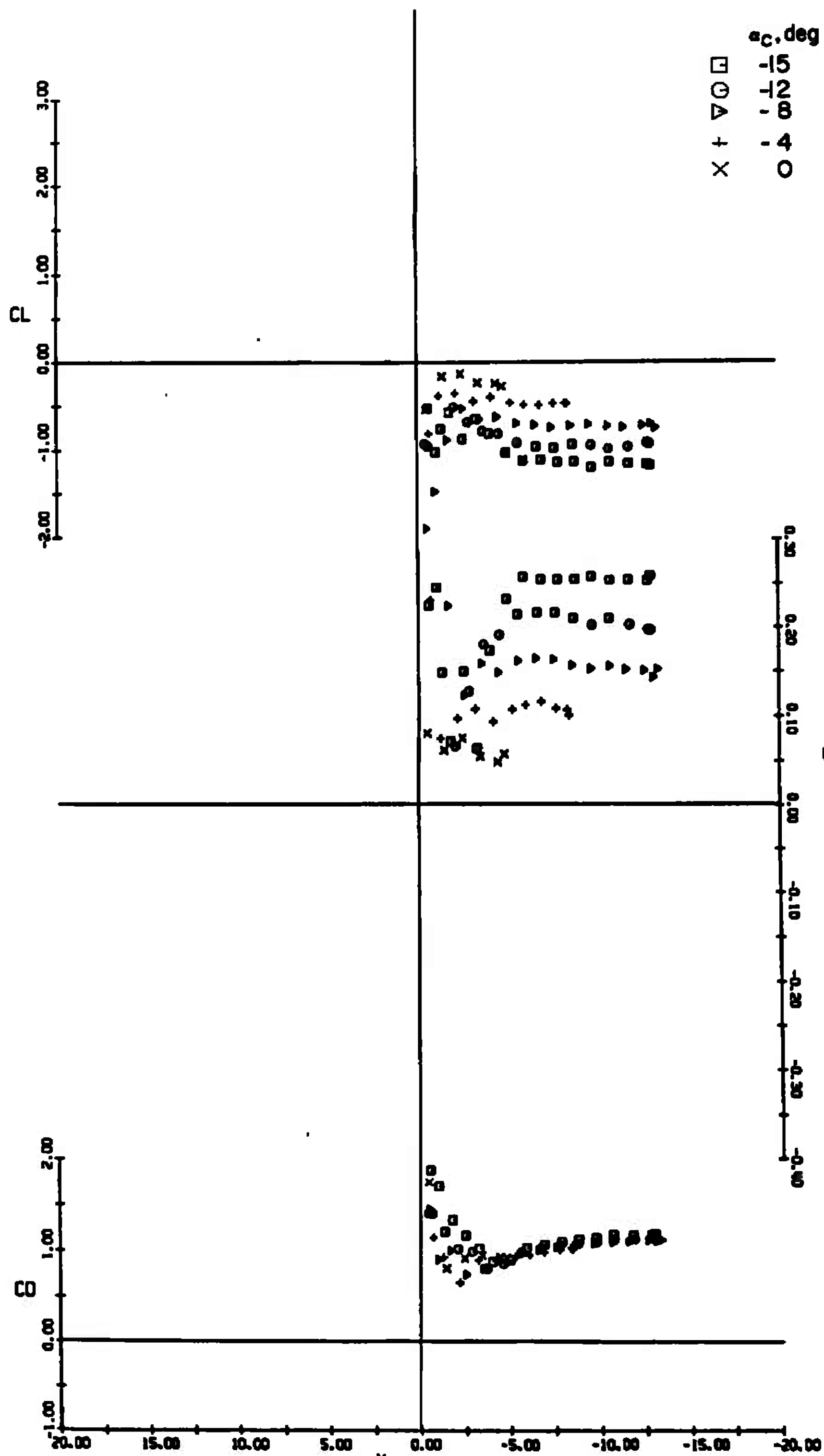

c. Z = 4 in.
Fig. 9 Continued




d. Z = 6 in.
Fig. 9 Continued

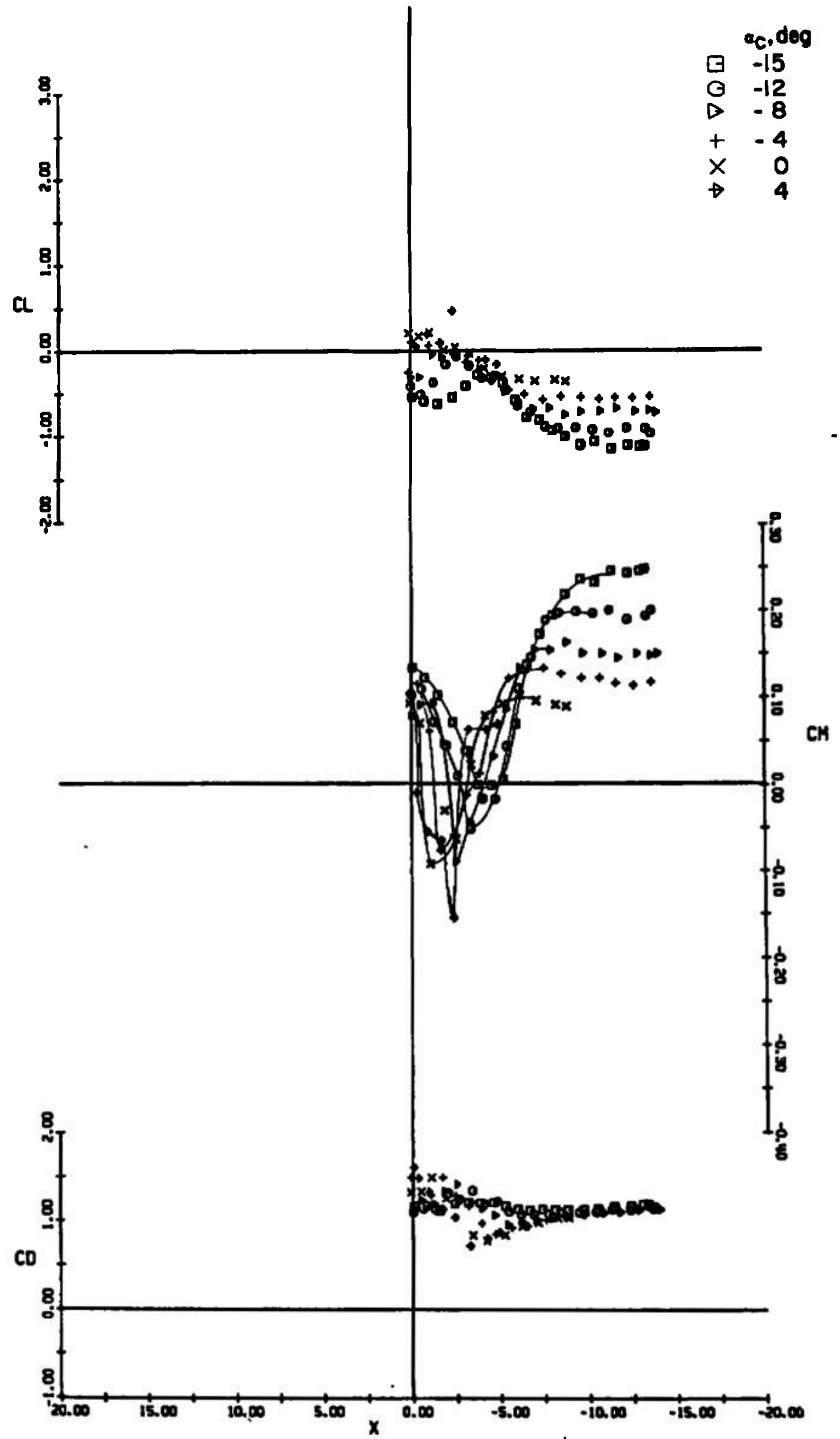



e. Z = 10 in.
Fig. 9 Concluded

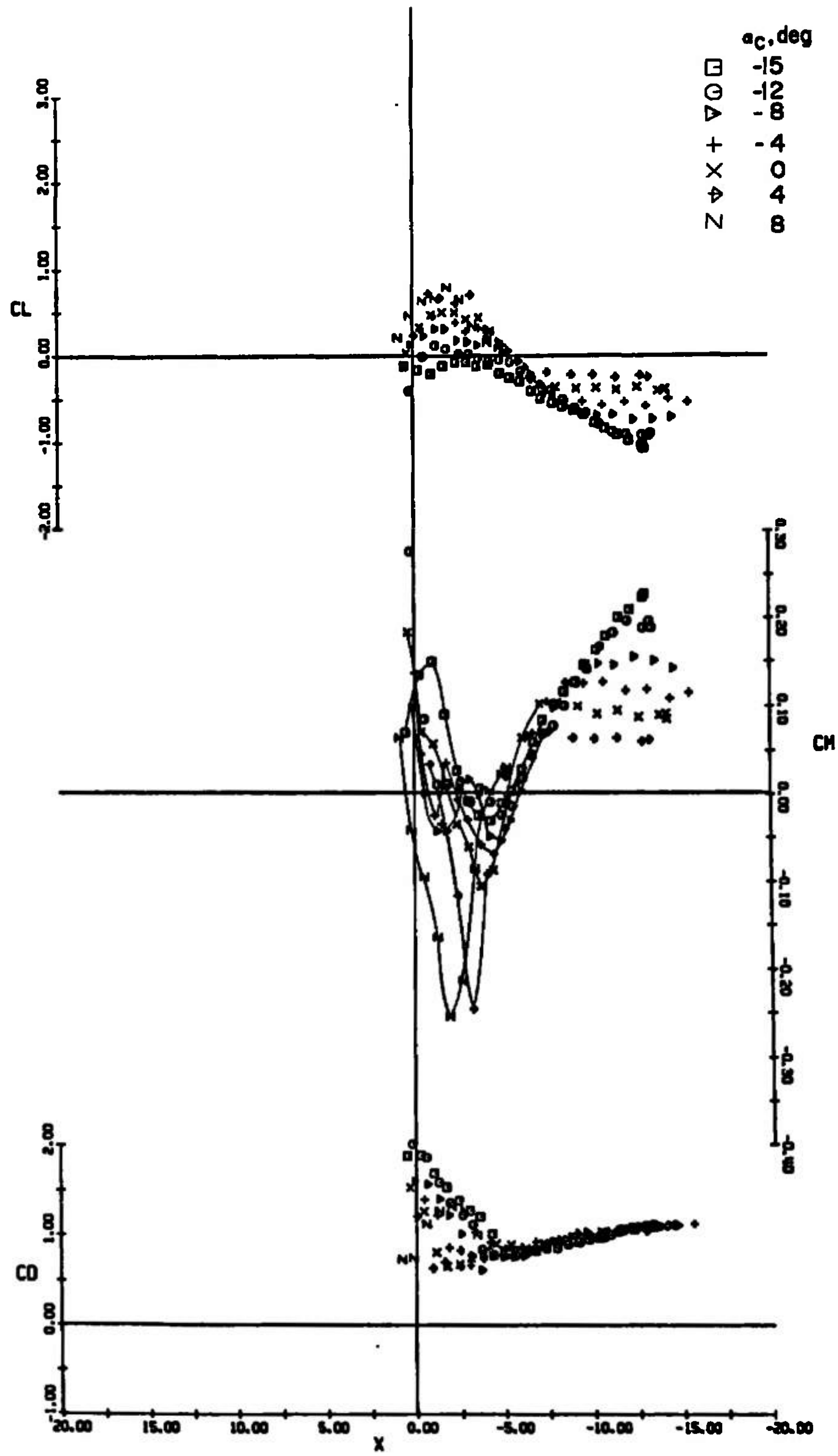



a. Z = 0 in.

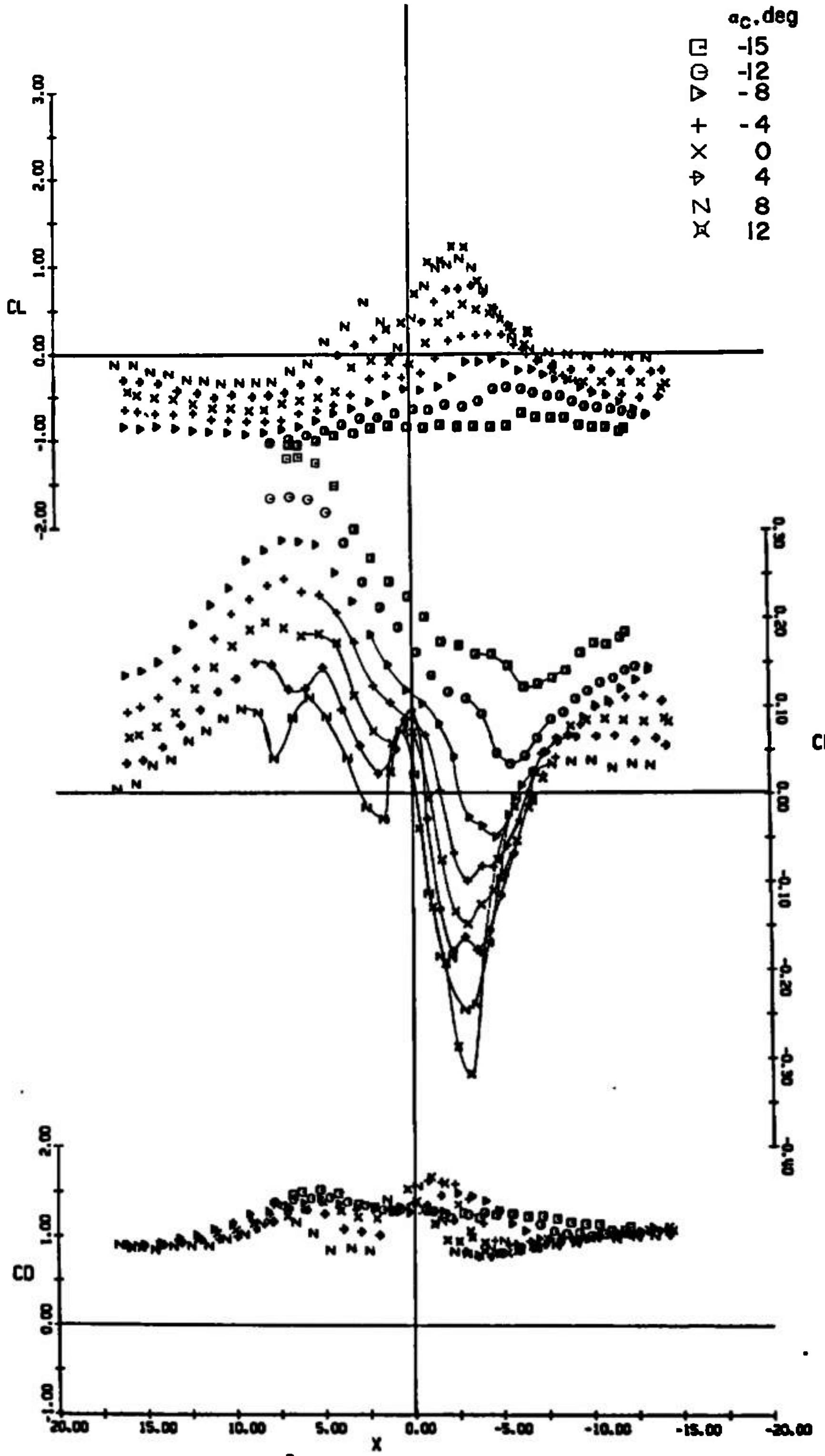
**Fig. 10 Lift, Pitching-Moment, and Drag Characteristics of the Capsule at Various Angles of Attack, Jet On, Y = 0, $M_\infty$ = 0.3**



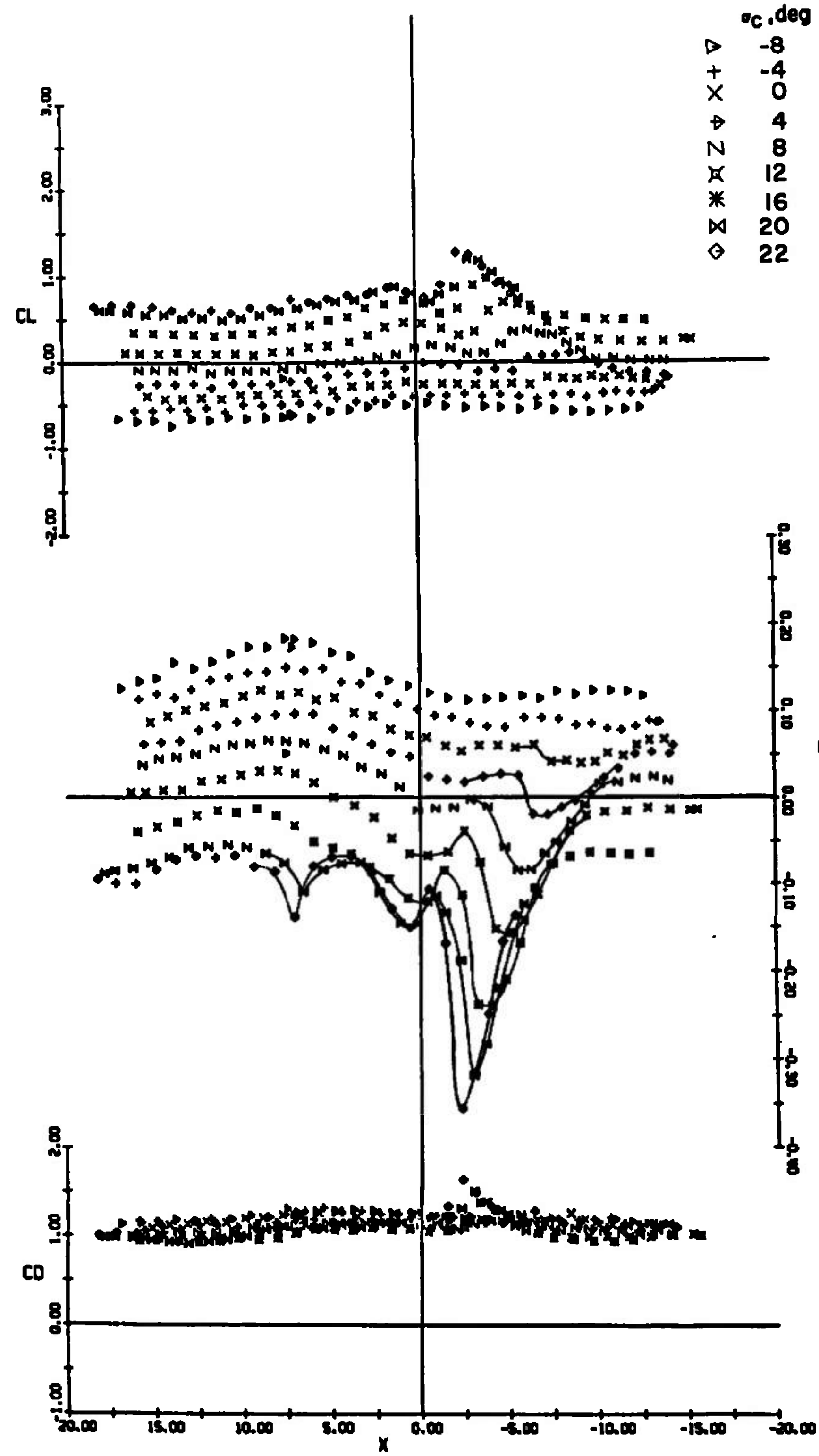

b. Z = 2 in.
Fig. 10 Continued



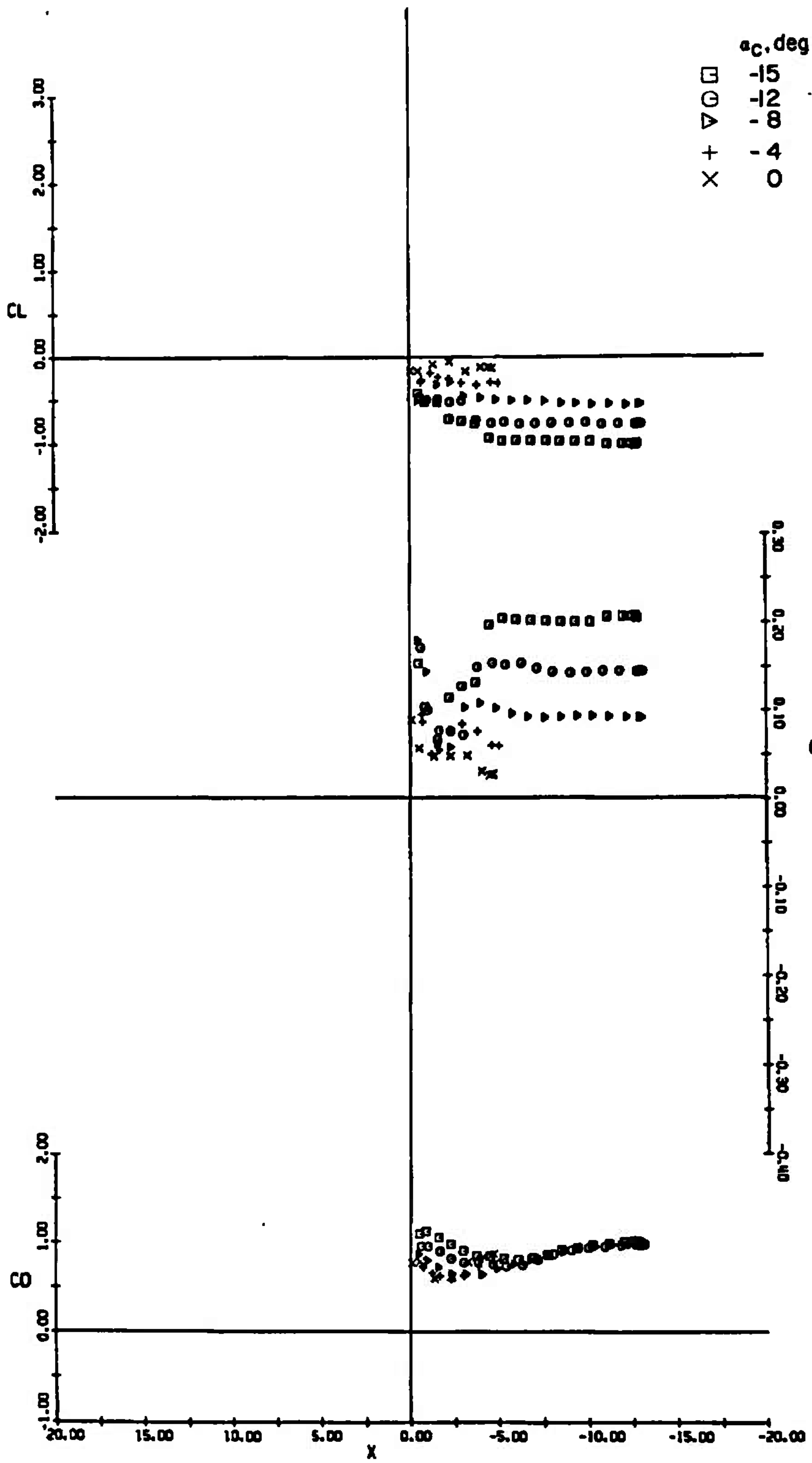

c. Z = 4 in.
Fig. 10 Continued




d. Z = 6 in.
Fig. 10 Continued

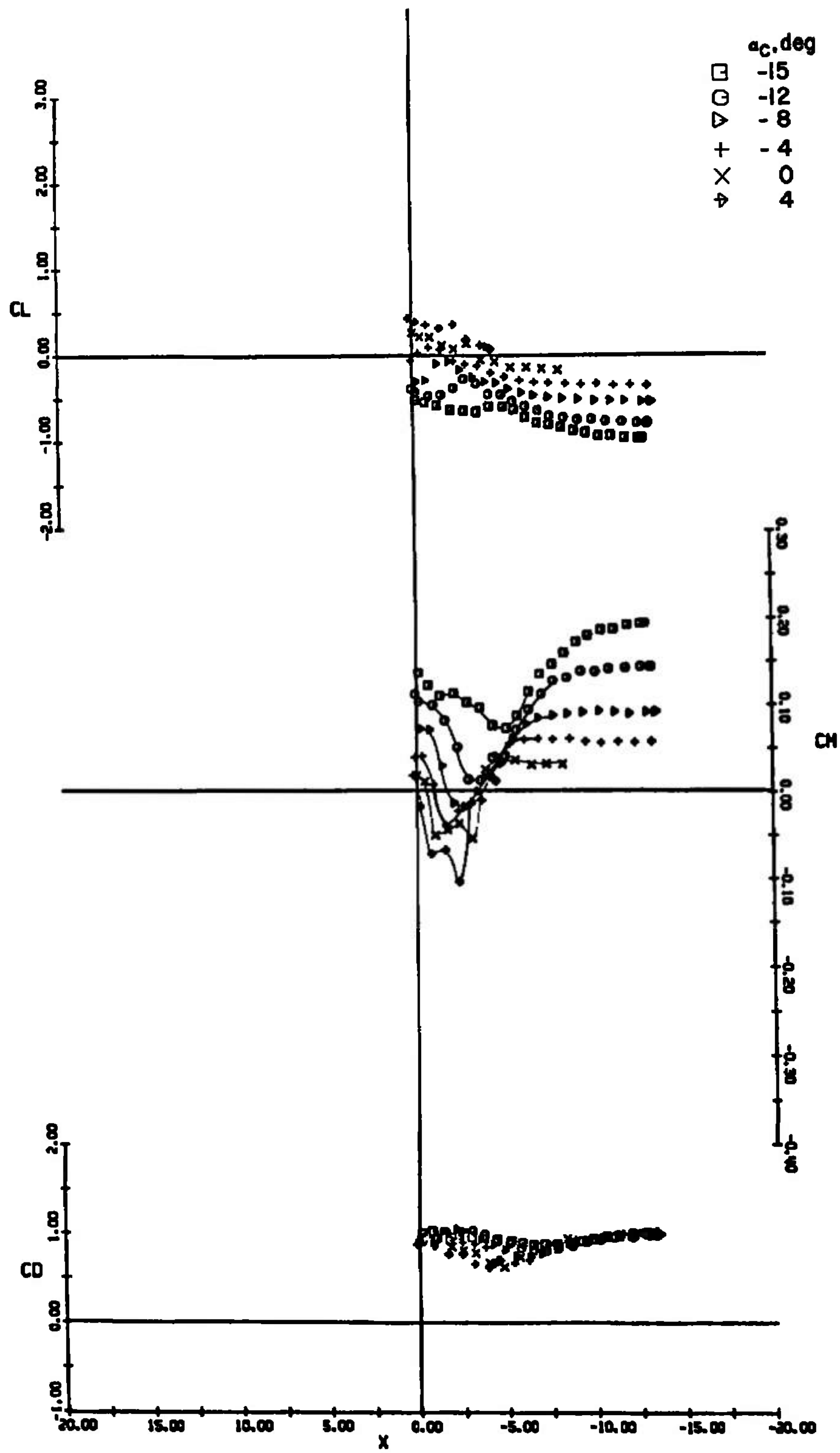



e. Z = 10 in.
Fig. 10 Concluded

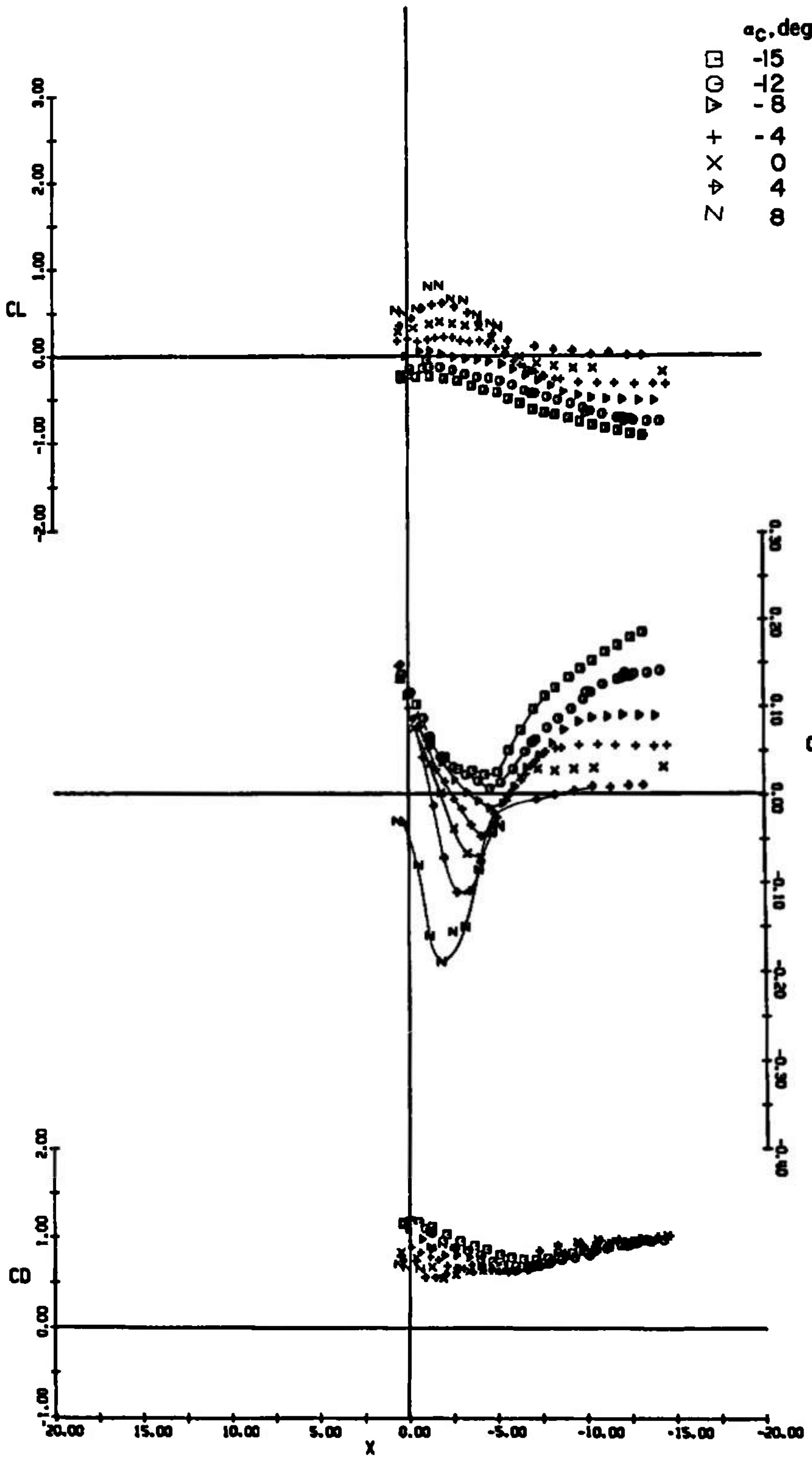



a. Z = 0 in.

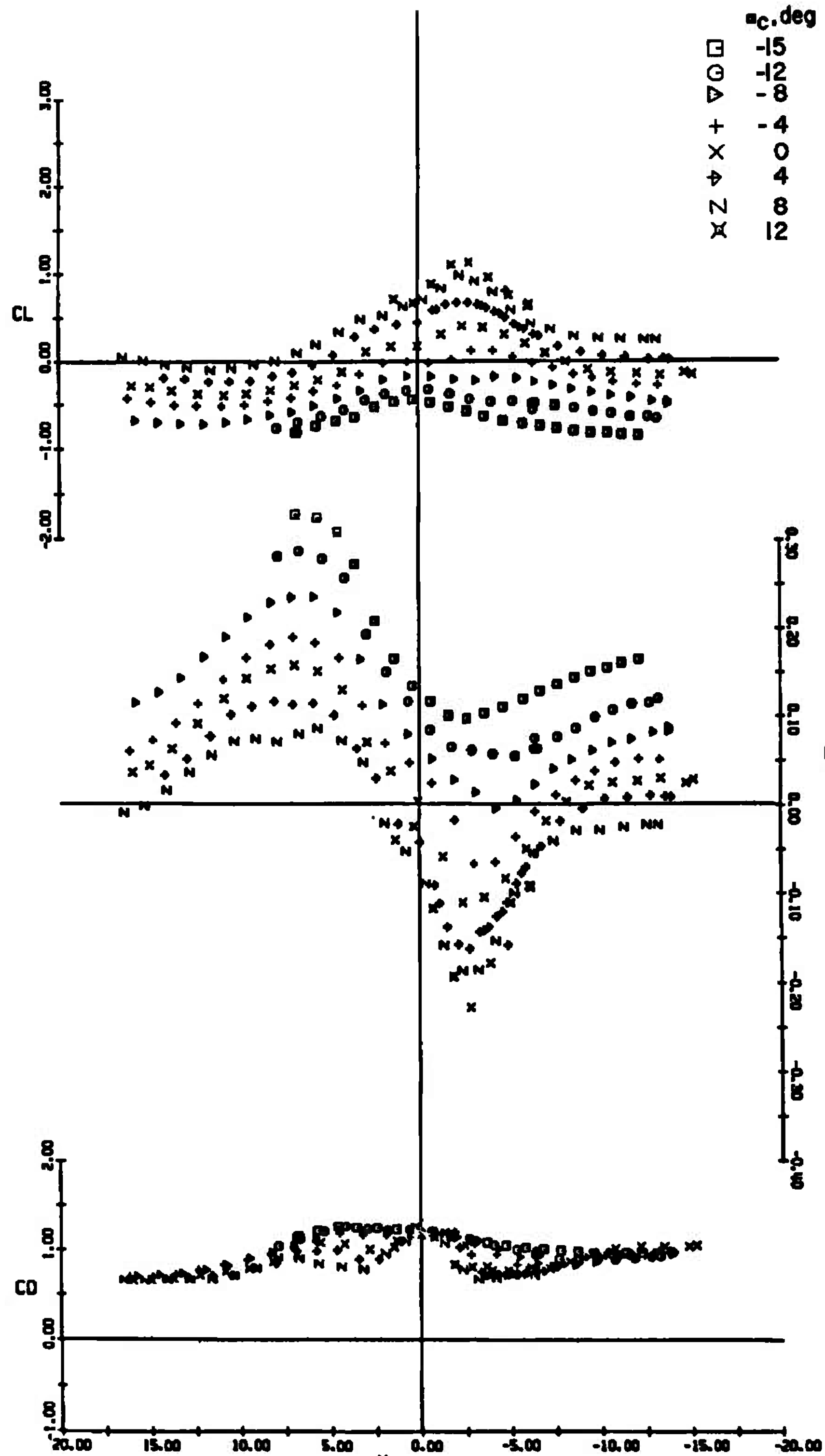
Fig. 11 Lift, Pitching-Moment, and Drag Characteristics of the Capsule at Various Angles of Attack, Jet On, Y = 0, $M_\infty$ = 0.6



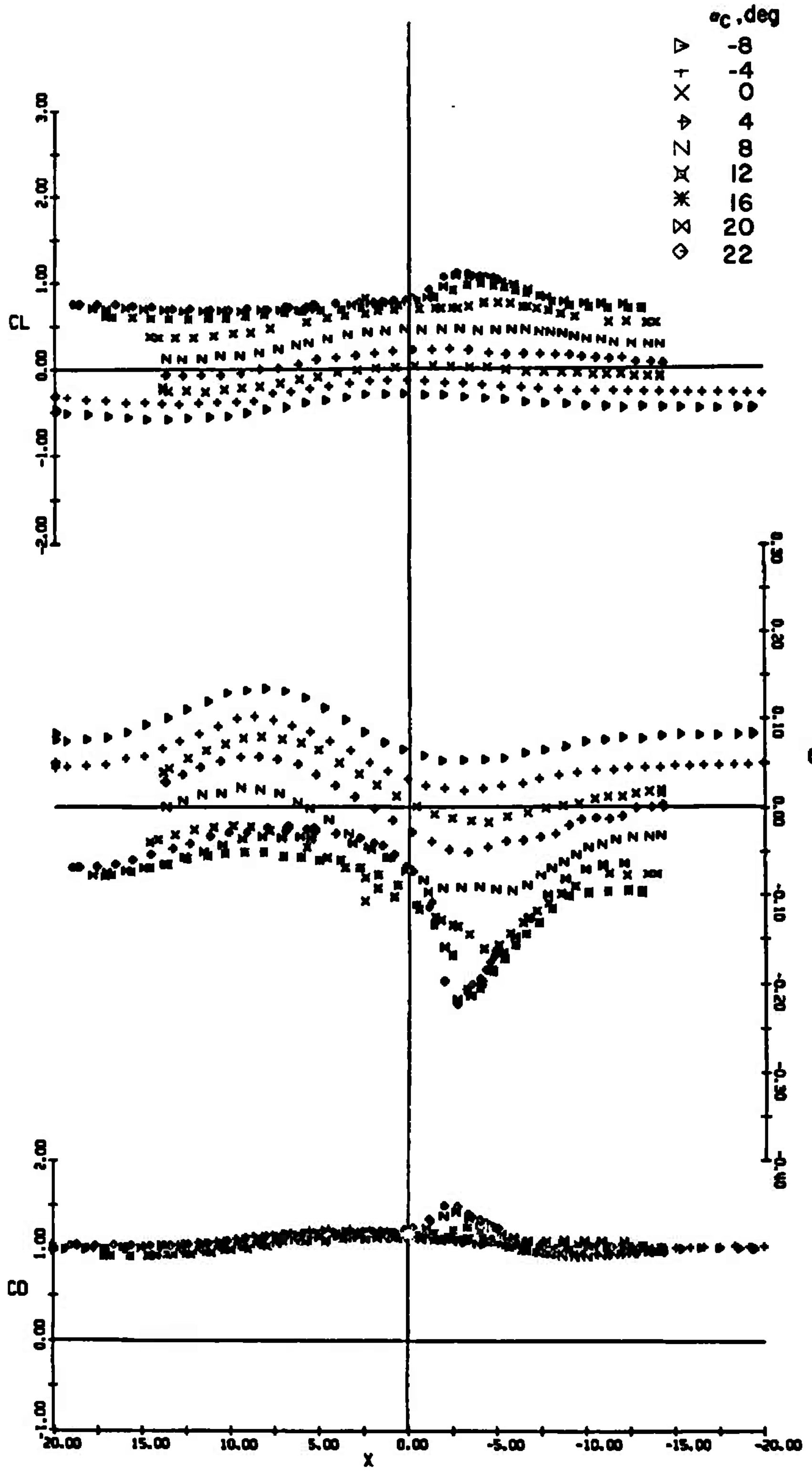

b. Z = 2 in.
Fig. 11 Continued



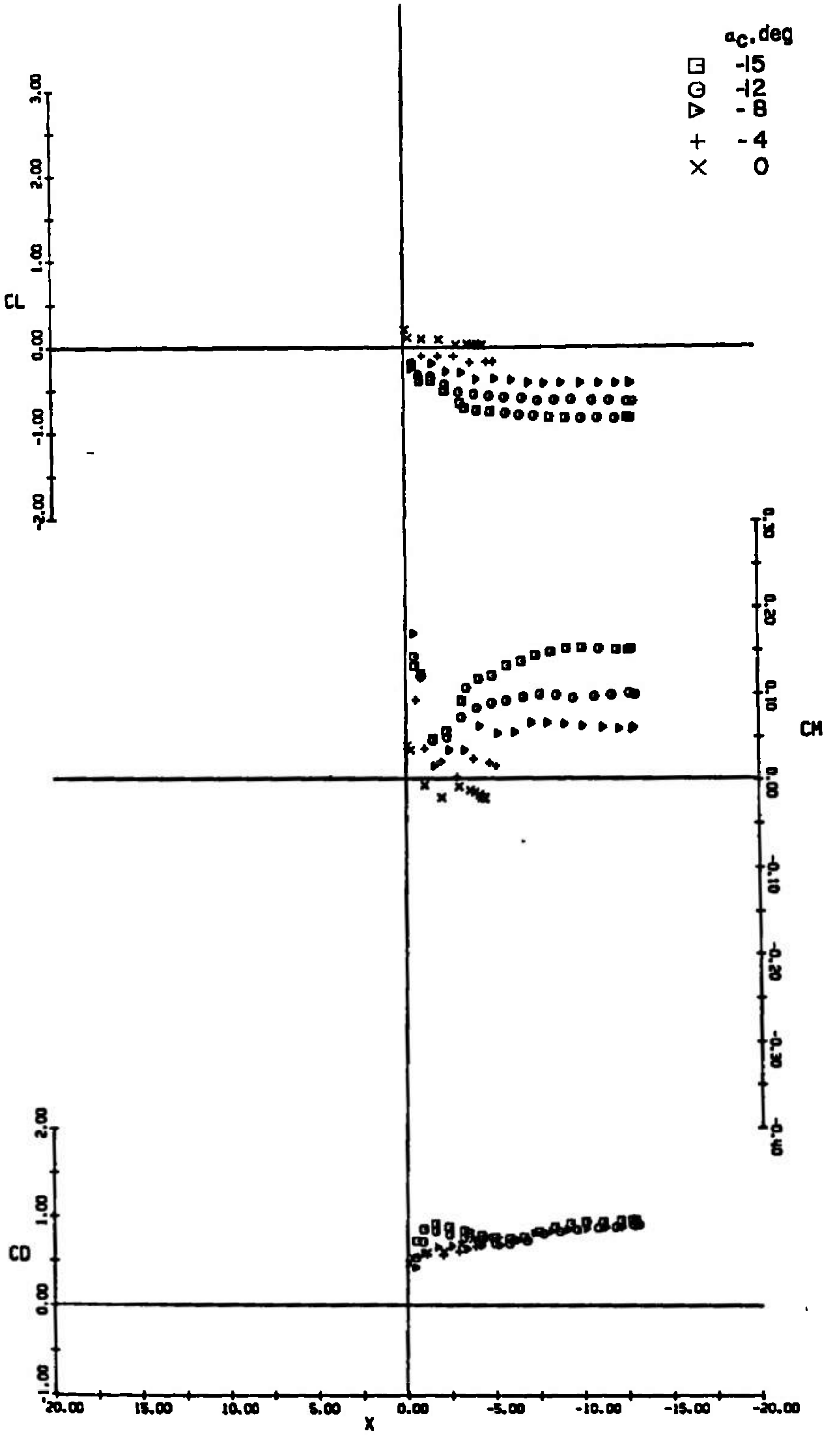

c. Z = 4 in.
Fig. 11 Continued




d. Z = 6 in.
Fig. 11 Continued

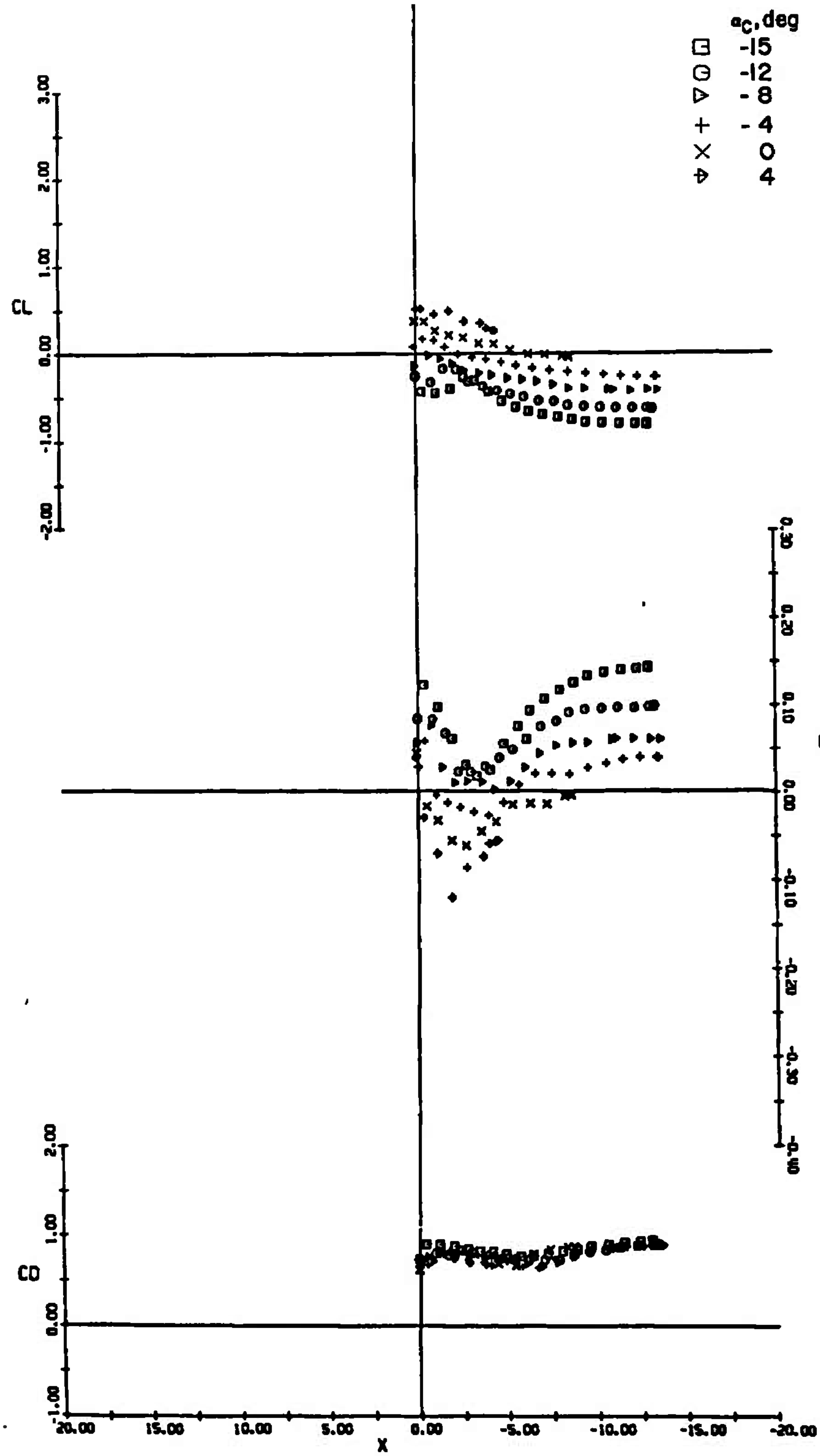



e. Z = 10 in.
Fig. 11 Concluded

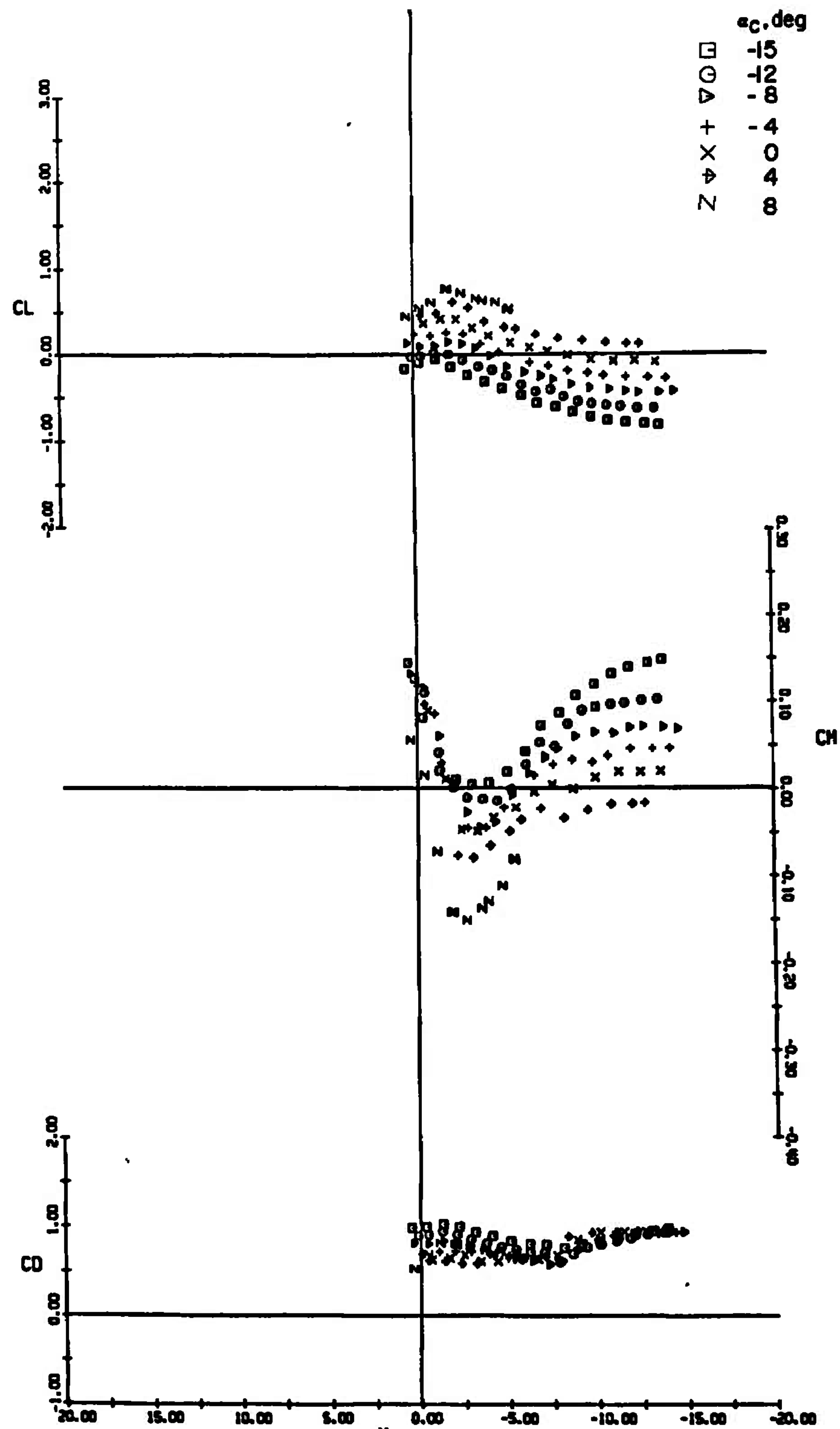



a. Z = 0 in.

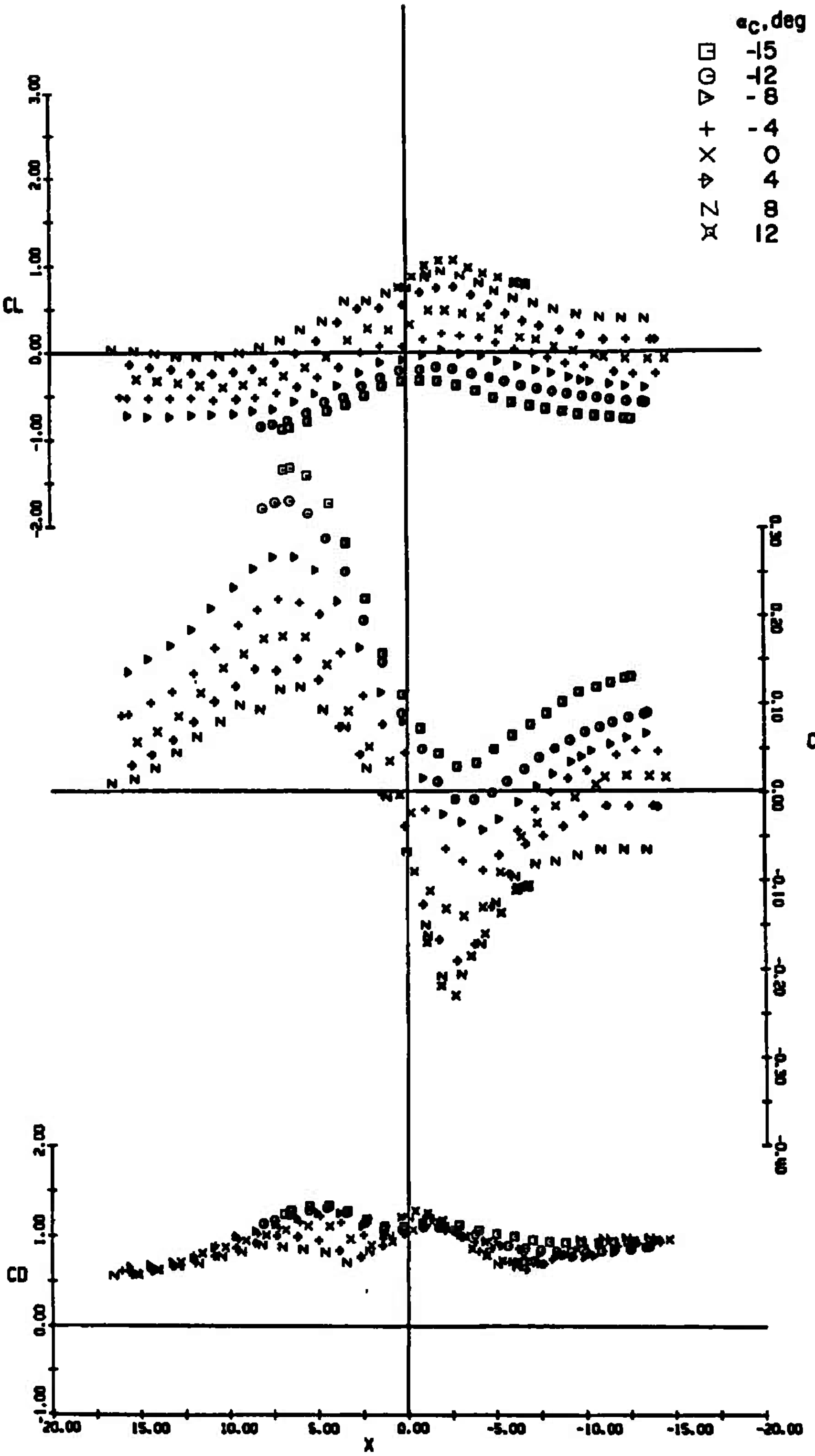
Fig. 12 Lift, Pitching-Moment, and Drag Characteristics of the Capsule at Various Angles of Attack, Jet On, Y = 0, $M_\infty$ = 0.9



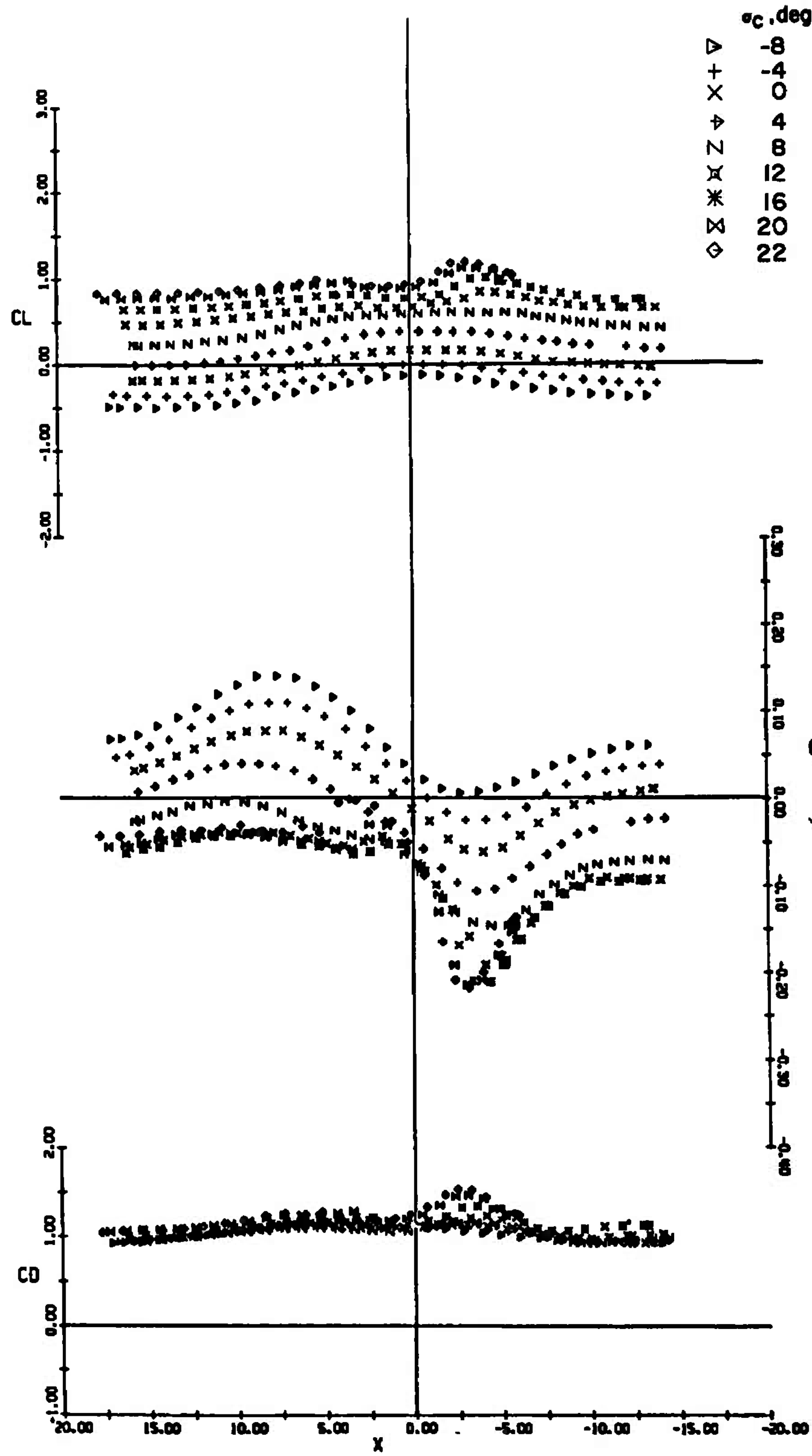

b. Z = 2 in.
Fig. 12 Continued



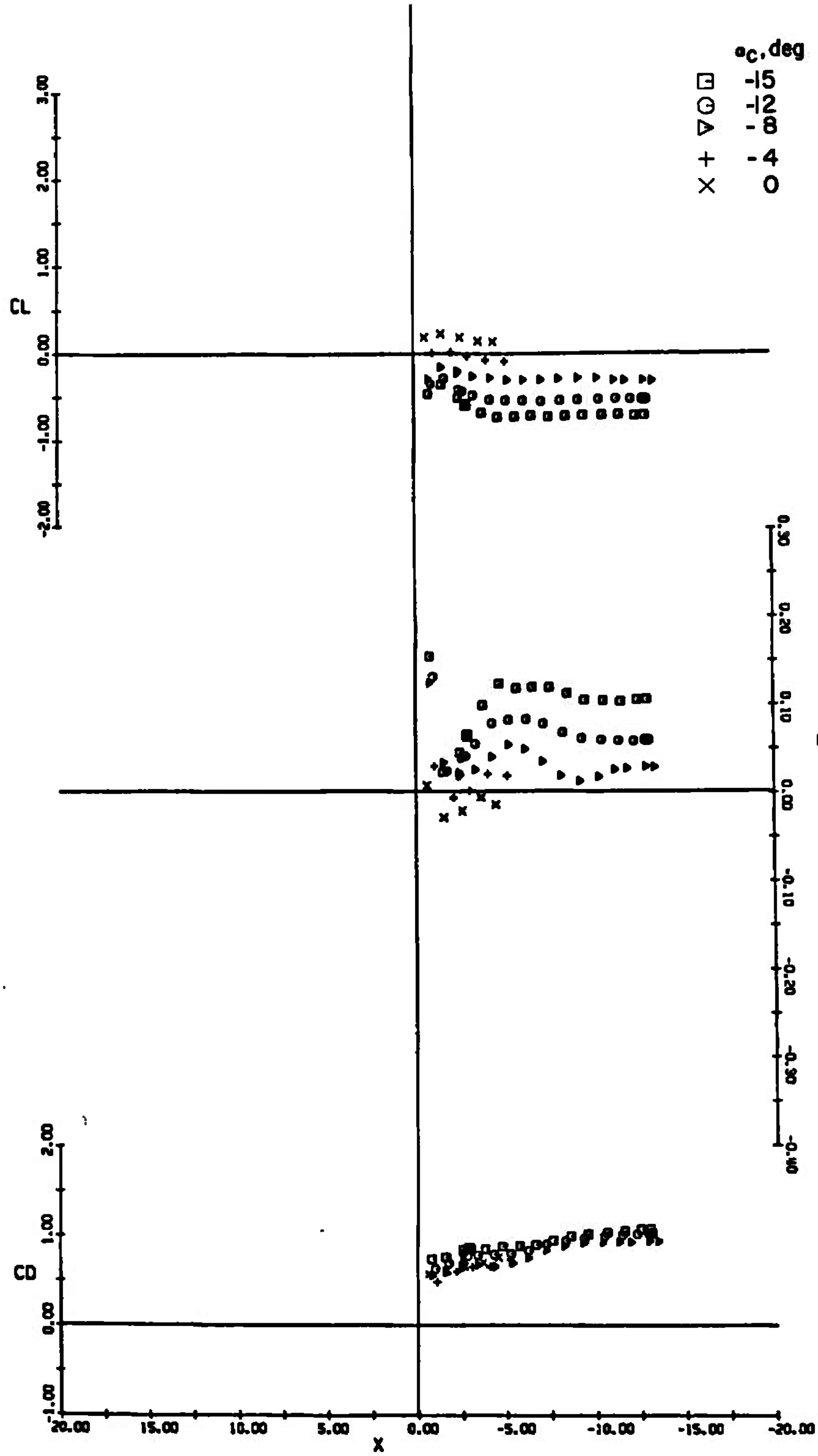

c. Z = 4 in.
Fig. 12 Continued




d. Z = 6 in.
Fig. 12 Continued

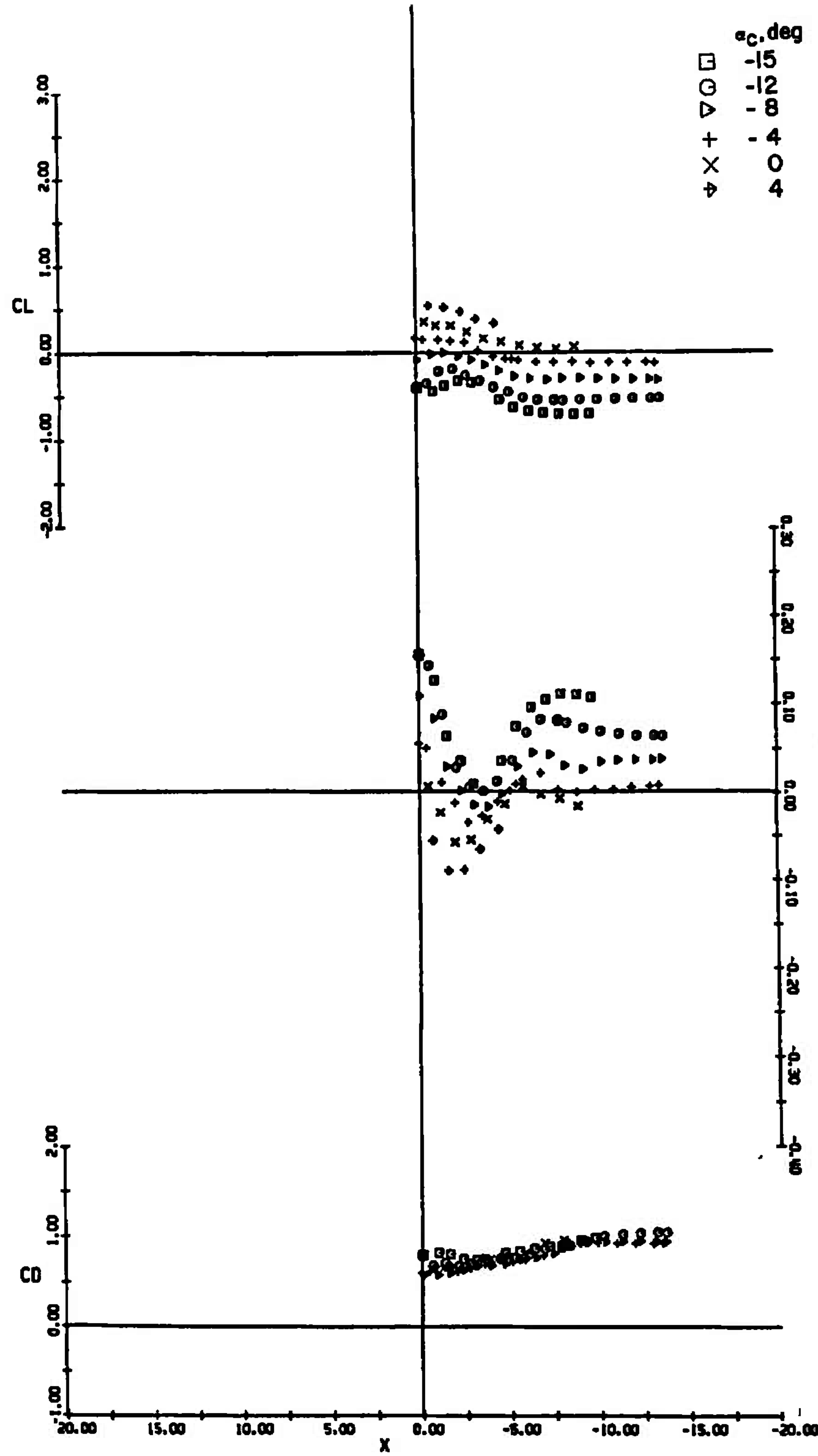



e. Z = 10 in.
Fig. 12 Concluded

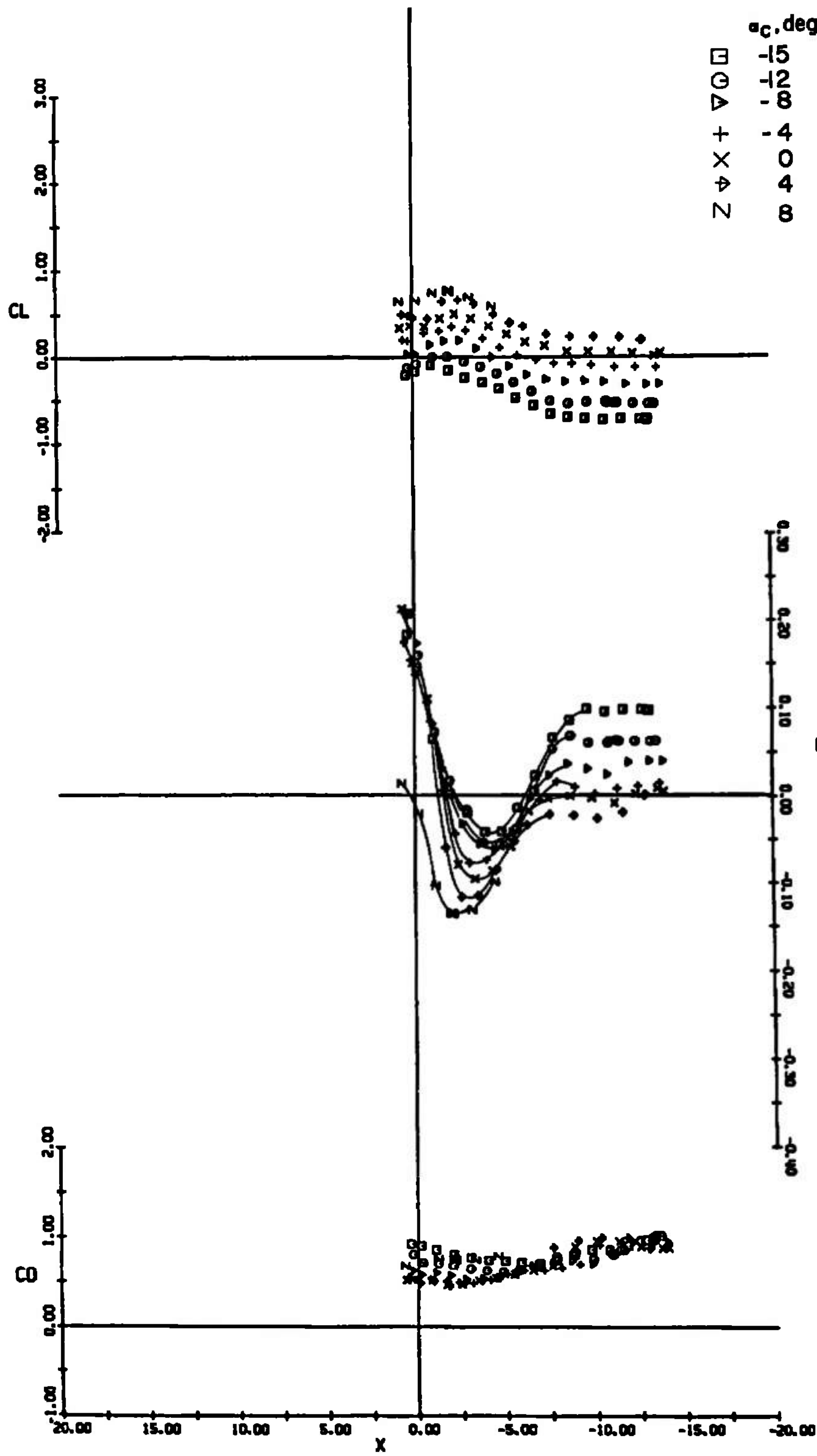



a. Z = 0 in.

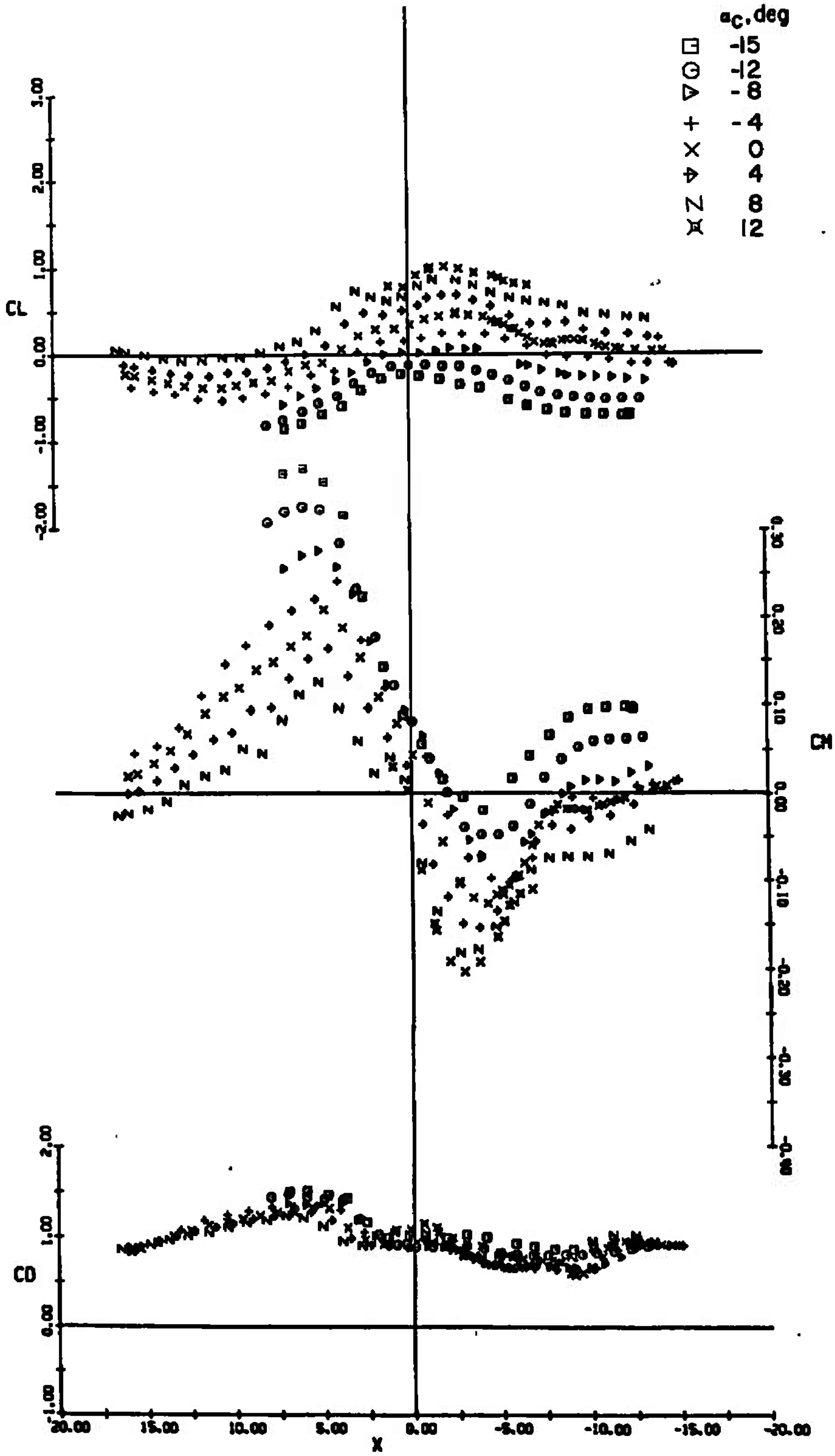
Fig. 13 Lift, Pitching-Moment, and Drag Characteristics of the Capsule at Various Angles of Attack, Jet On, Y = 0, $M_\infty$ 1.2



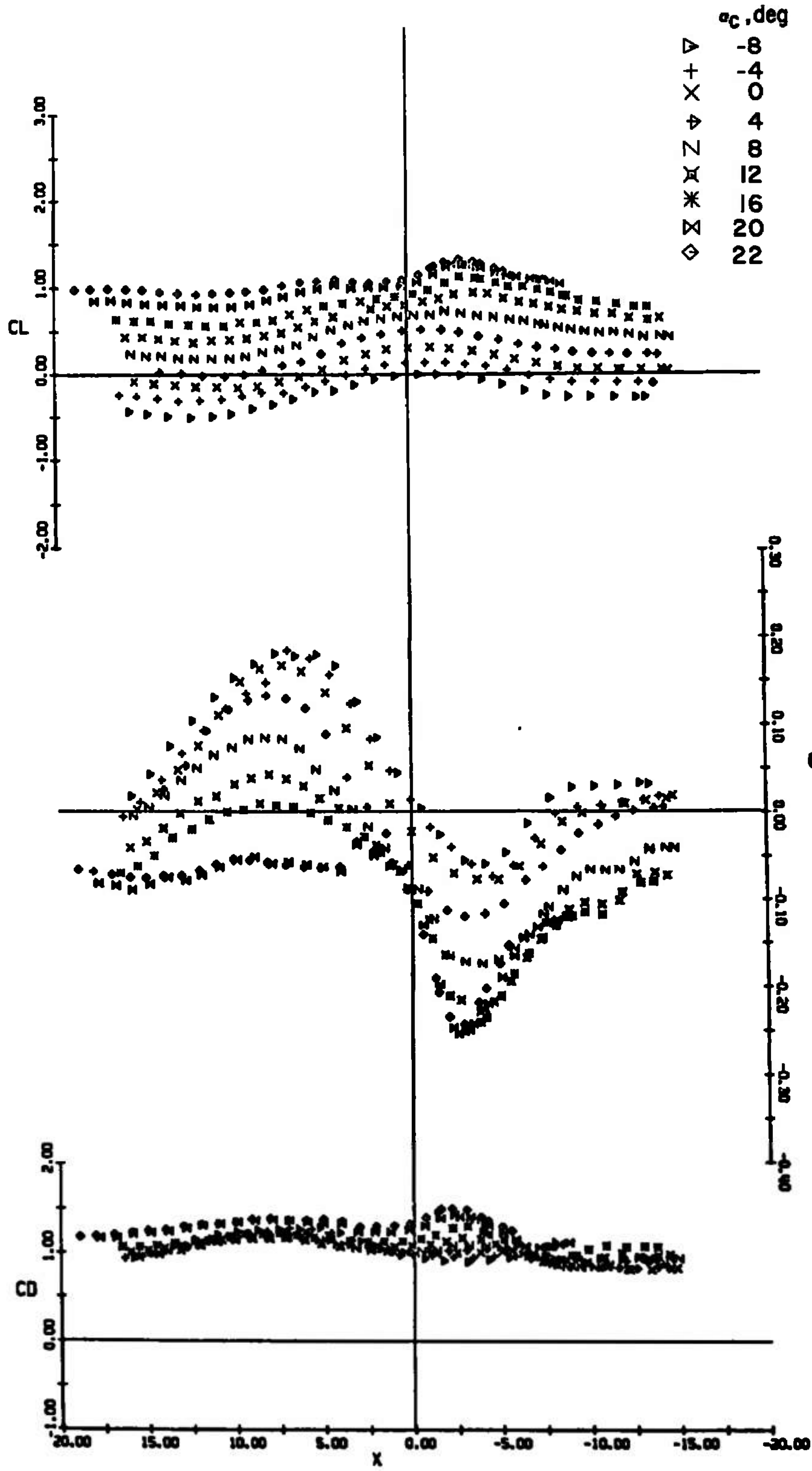

b. Z = 2 in.
Fig. 13 Continued



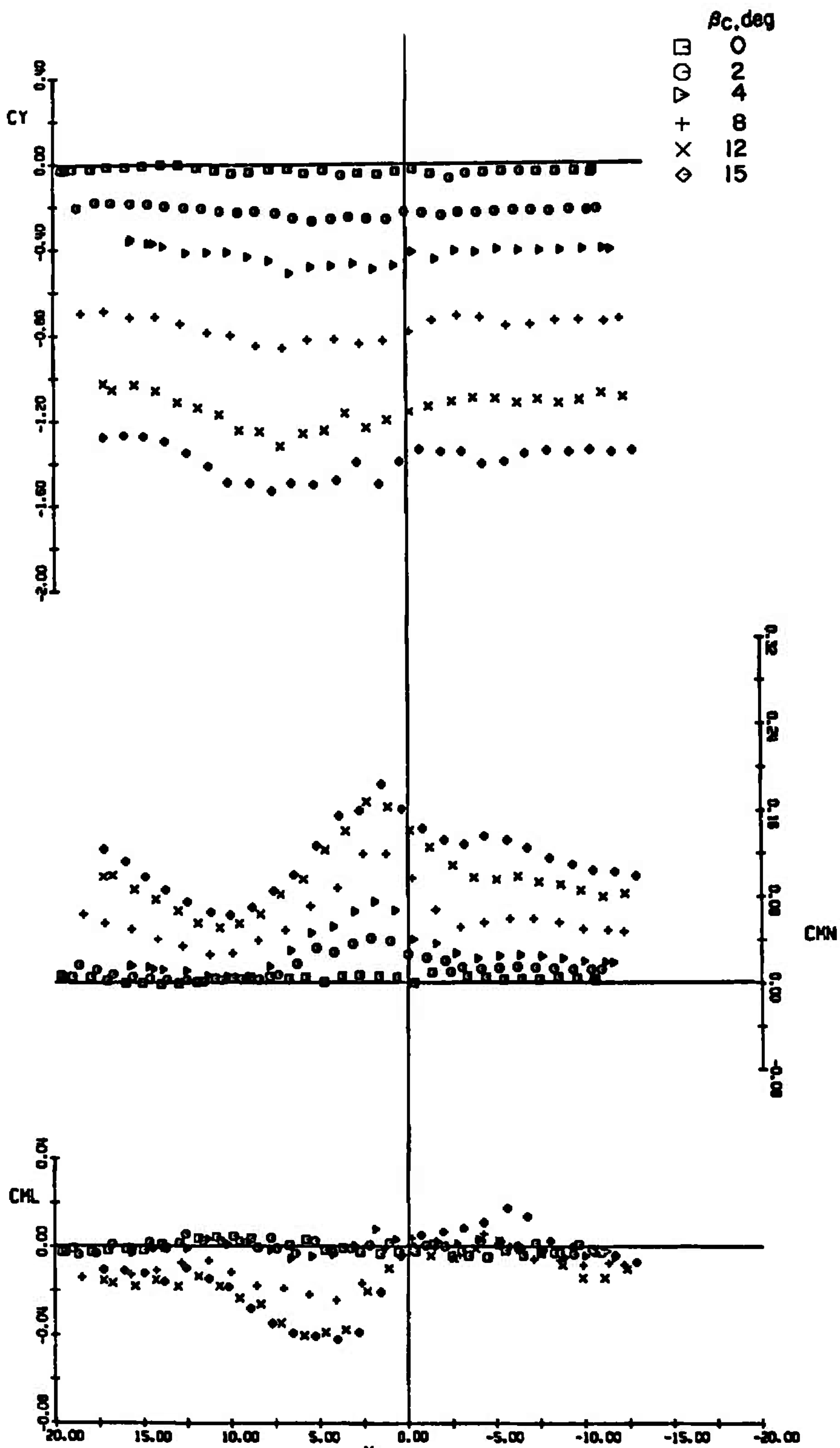

c. Z = 4 in.
Fig. 13 Continued




d. Z = 6 in.
Fig. 13 Continued

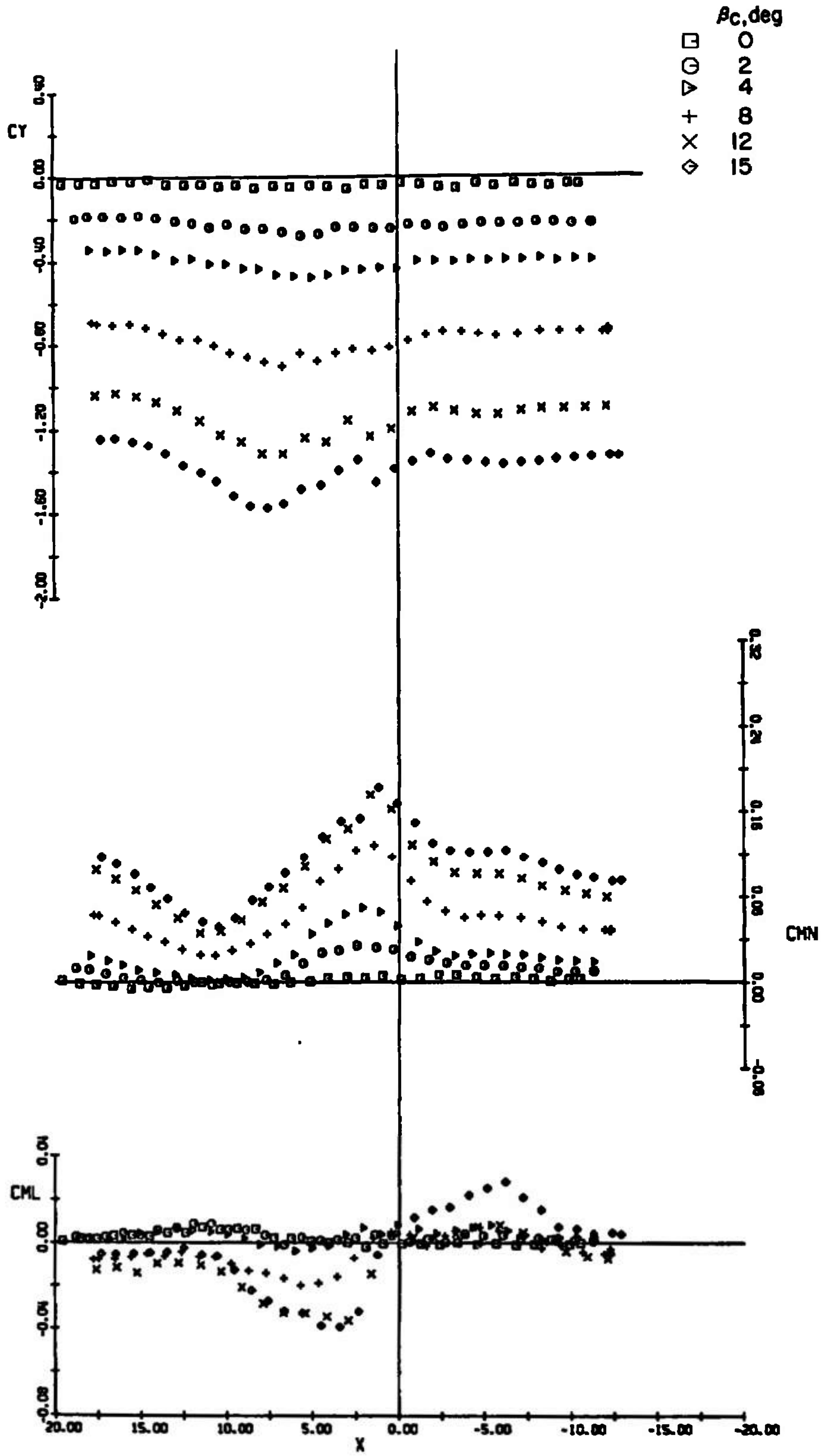



e. Z = 10 in.
Fig. 13 Concluded

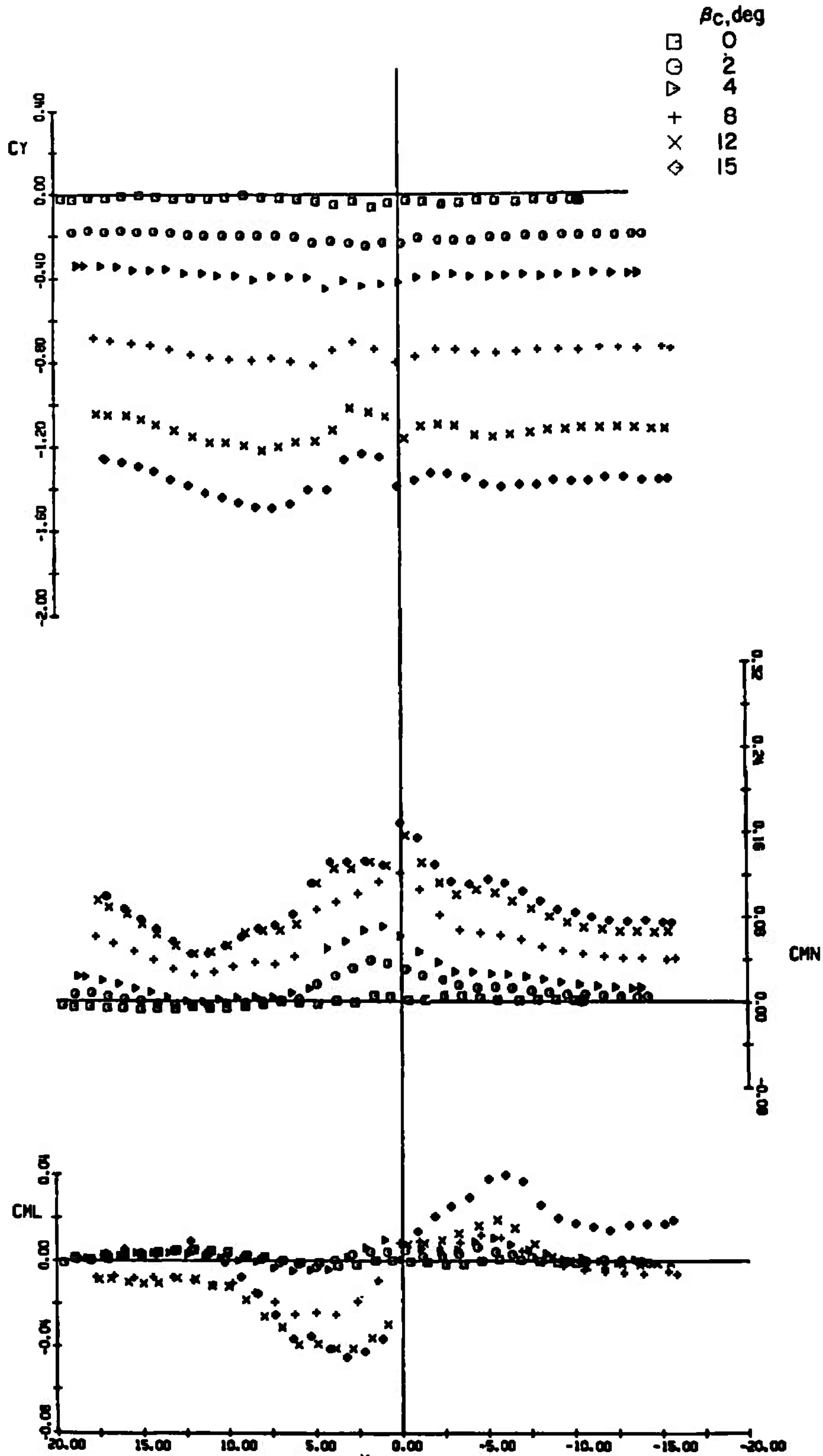



a. $M_\infty = 0.3$

Fig. 14 Side-Force, Yawing-Moment, and Rolling-Moment Characteristics of the Capsule, Jet Off, Y = 0, Z = 6 in.

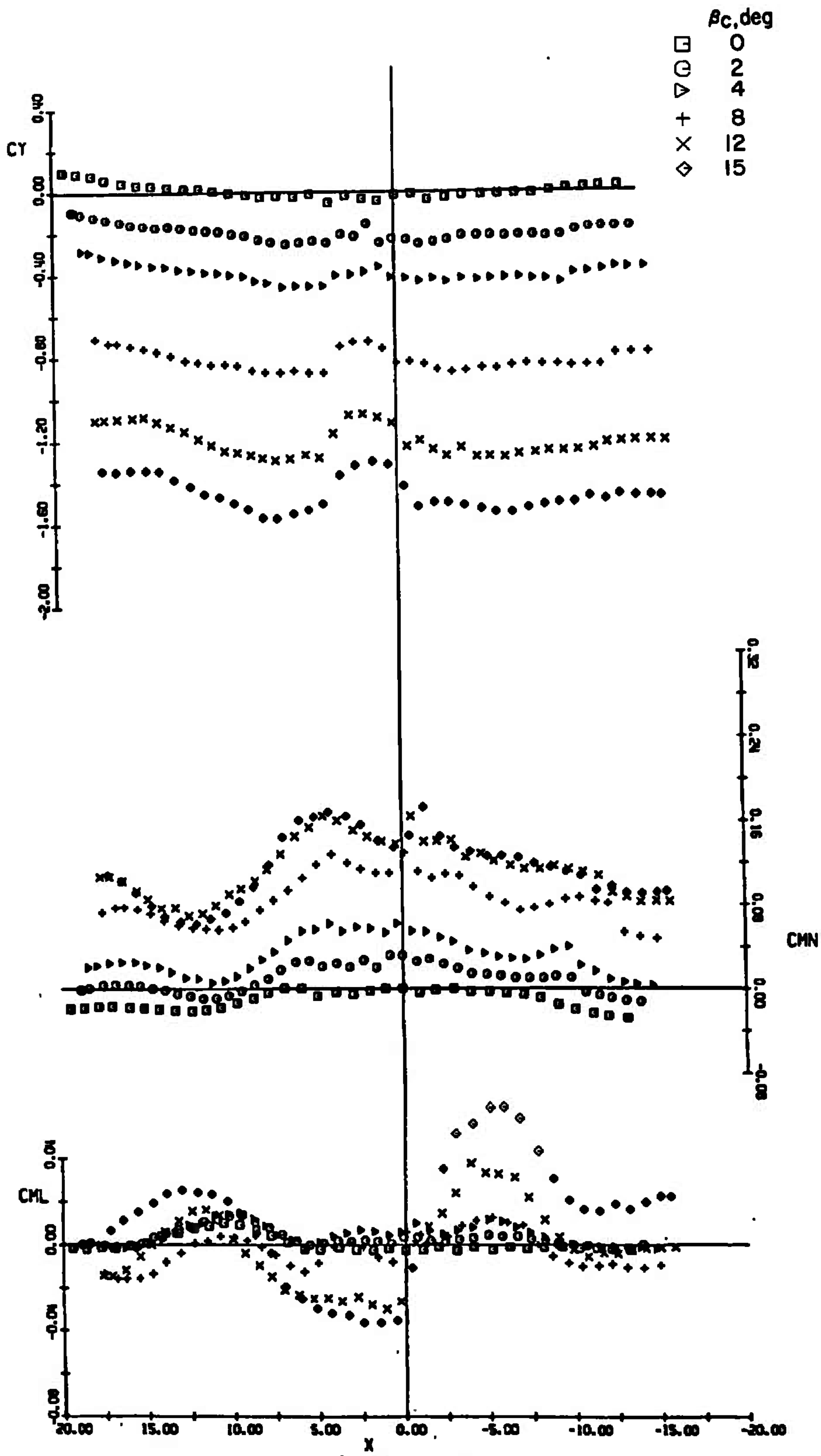



b. $M_\infty = 0.6$
Fig. 14 Continued



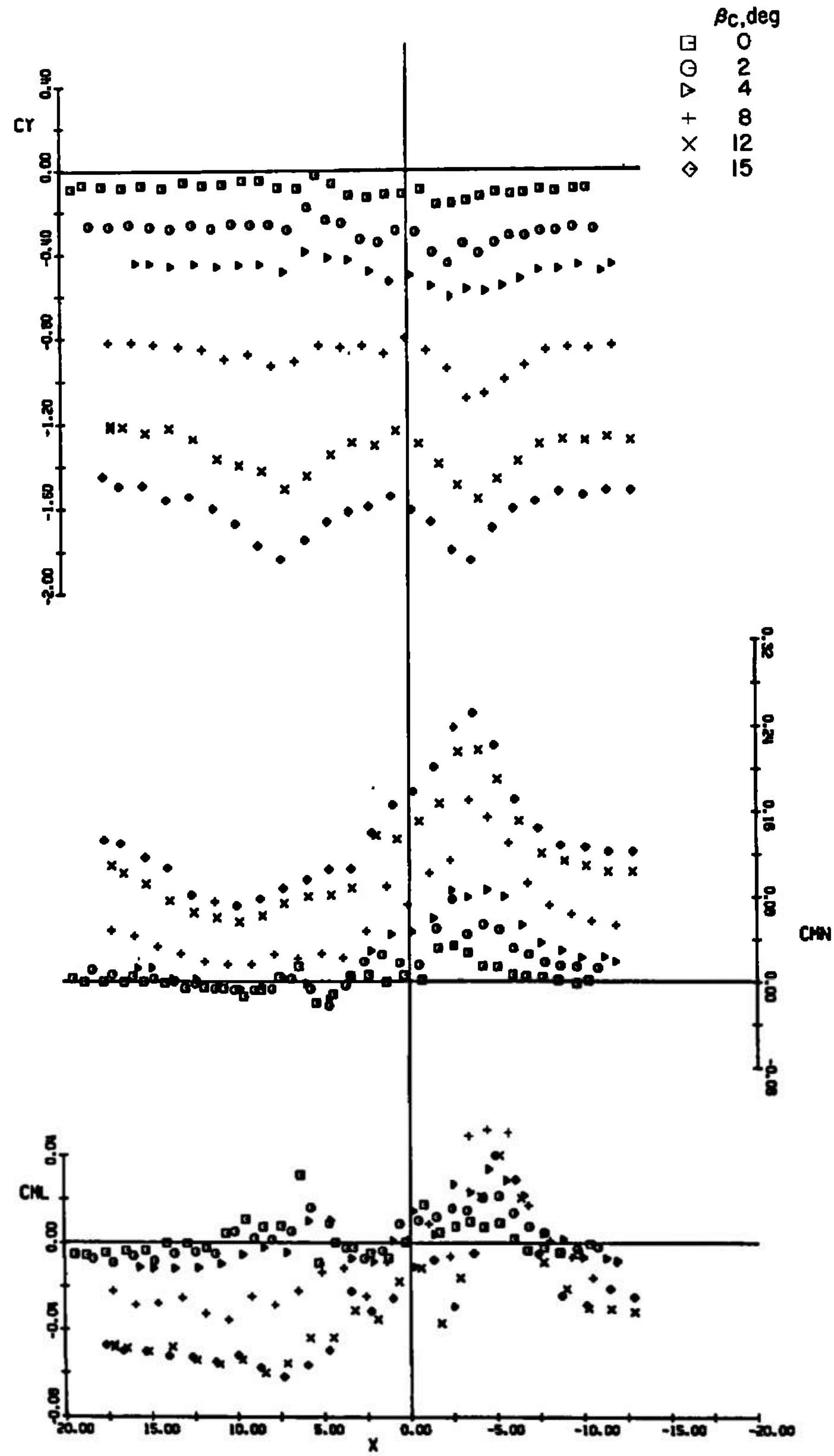

c. $M_\infty = 0.9$

Fig. 14 Continued



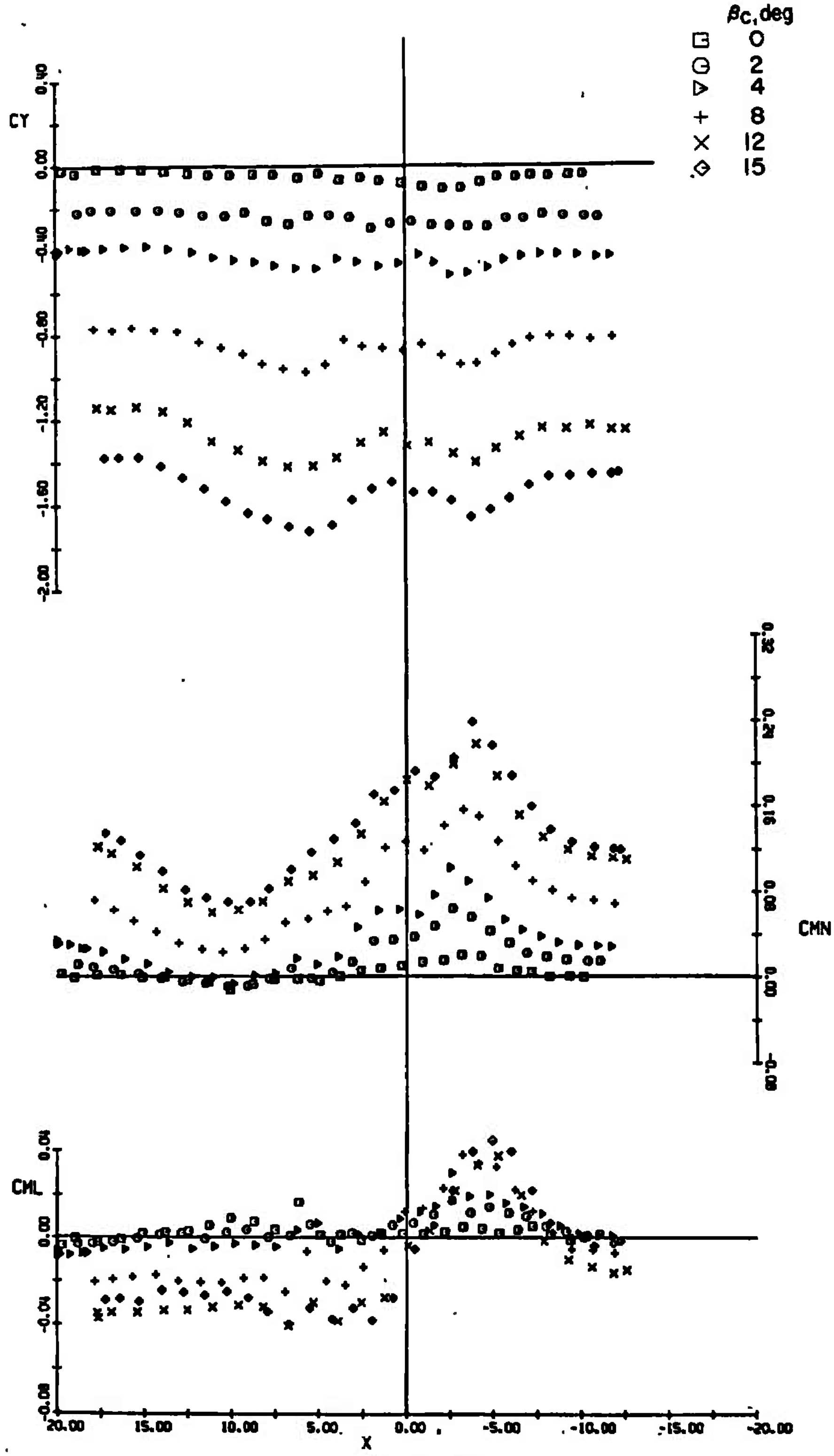

d. $M_\infty = 1.2$

Fig. 14 Concluded

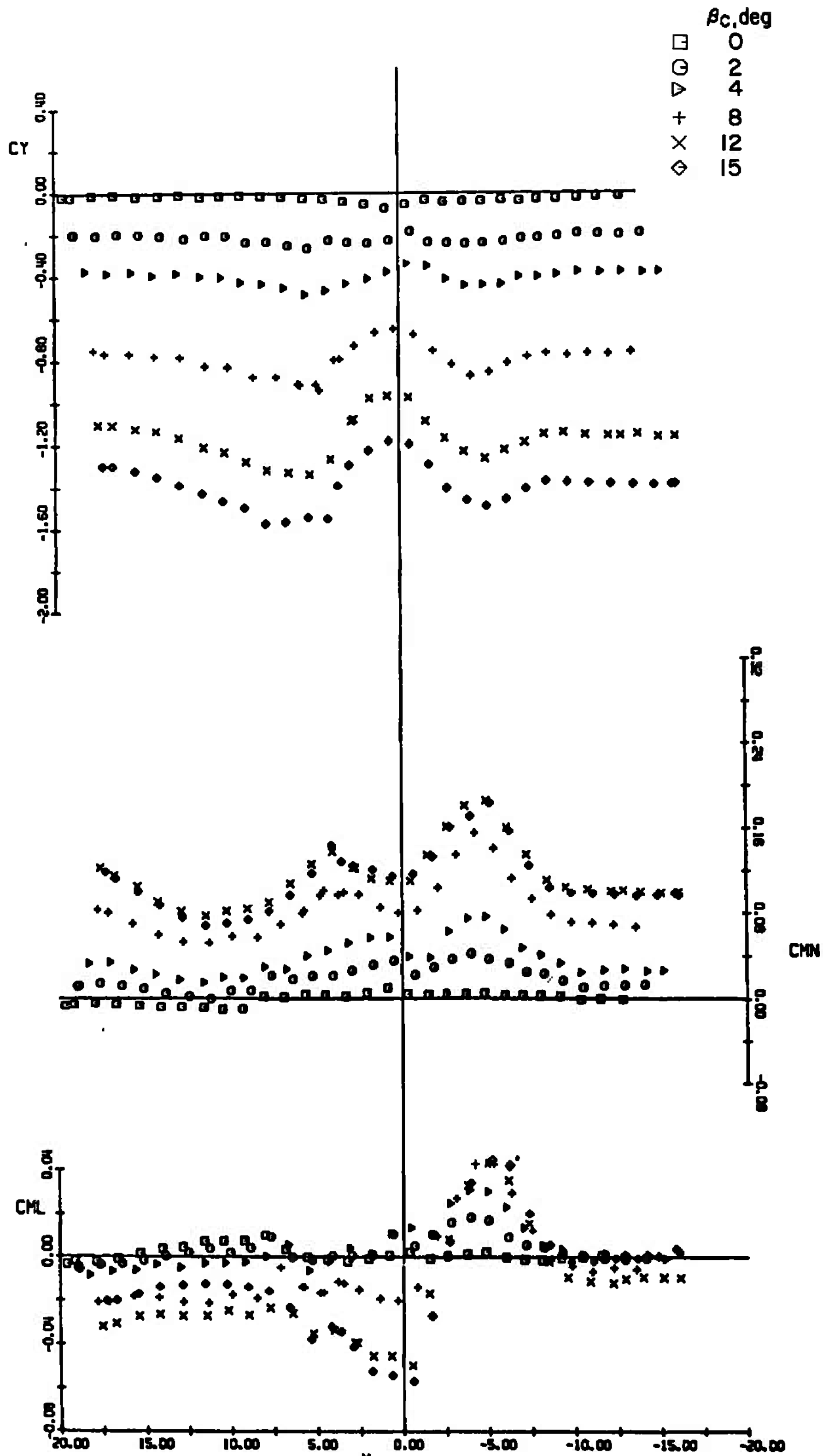



a. $M_\infty = 0.3$

Fig. 15 Side-Force, Yawing-Moment, and Rolling-Moment Characteristics of the Capsule, Jet On, Y = 0, Z = 6 in.

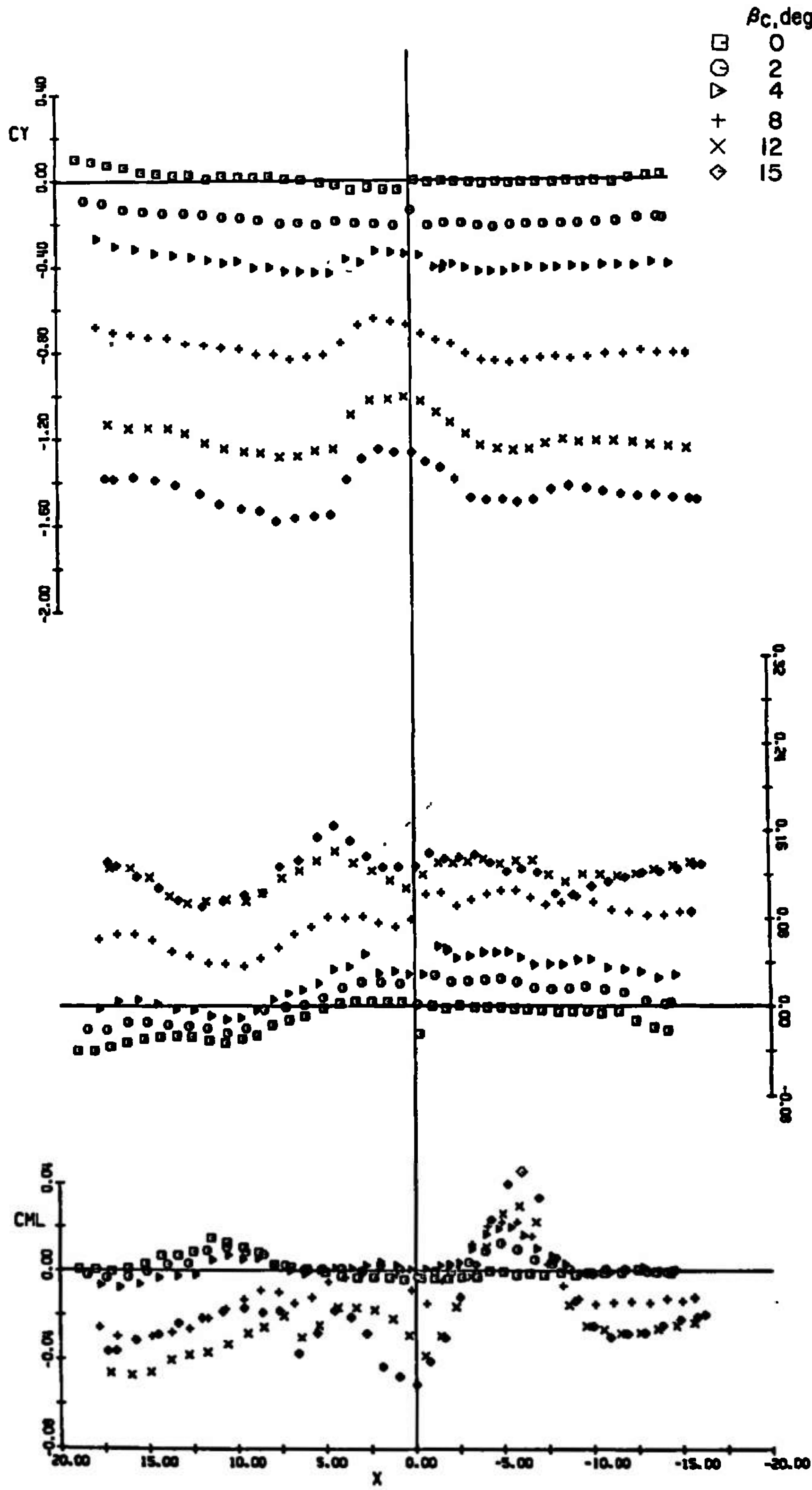



b. $M_\infty = 0.6$
Fig. 15 Continued




c. $M_\infty = 0.9$

Fig. 15 Continued




d. $M_\infty = 1.2$
Fig. 15 Concluded

## TABLE I
## TEST CONDITIONS

| Nominal $M_\infty$ | Simulated Pressure Altitude, ft | $p_c/p_\infty$ |
|---|---|---|
| 0.3 | 0 | 1*, 40.8 |
| 0.6 | 0 | 1, 40.8 |
| 0.9 | 19,160 | 1, 85.7 |
| 1.2 | 30,040 | 1, 137.5 |

*Jet off

## TABLE II
## SUMMARY OF MODEL ATTITUDES TESTED

| Z, in. | Y, in. | $\alpha_c$, deg | $\beta_c$, deg |
|---|---|---|---|
| 0 | 0 | -15*, -12*, -8*, -4*, 0* | 0 |
| 1 | | -15*, -12*, -8*, -4*, 0*, 2* | |
| 2 | | -15*, -12*, -8*, -4*, 0* 4* | |
| 3 | | -15, -12, -8, -4, 0, 4*, 6* | |
| 4 | | -15, -12, -8, -4, 0, 4, 8* | |
| 5 | | -15, -12, -8, -4, 0, 4, 8, 10 | |
| 6 | | -15, -12, -8, -4, 0, 4, 8, 12 | |
| 10 | | -8, -4, 0, 4, 8, 12, 16, 20, 22 | |
| 6 | 0 | 0 | 0, 2, 4, 8, 12, 15 |
| 6 | 5 | 0 | 0, 2, 4, 8, 12, 15 |

*Fuselage door open

## TABLE III
## PRECISION OF DATA

| | $M_\infty = 0.6$ | $M_\infty = 1.2$ |
|---|---|---|
| $M_\infty$ | ±0.005 | ±0.010 |
| CL | ±0.0731 | ±0.0760 |
| CM | ±0.0047 | ±0.0051 |
| CD | ±0.0524 | ±0.0624 |
| CY | ±0.0206 | ±0.0212 |
| CMN | ±0.0028 | ±0.0028 |
| CML | ±0.0019 | ±0.0021 |

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13. ABSTRACT


Static force tests were conducted on a separable-nose crew escape capsule in the presence of the forward section of an airplane fuselage. The capsule escape rocket exhaust plume was simulated with high-pressure air heated to a total temperature of approximately 100°F. Data were obtained at Mach numbers of 0.3, 0.6, 0.9, and 1.2 at capsule angles of attack from -15 to 22 deg and angles of sideslip from 0 to 15 deg for various positions of the capsule relative to the fuselage section. All testing was conducted with the fuselage at zero-degree angle of attack and zero-degree sideslip. Data were obtained both with and without rocket exhaust plume simulation. With the capsule at angle of attack, the most significant interference was on pitching moment. The most significant effects with the capsule at sideslip angles were on rolling and yawing moments. The magnitude and extent of the interference effects were larger with the jet on than with the jet off.


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| 14. KEY WORDS | LINK A | | LINK B | | LINK C | |
|---|---|---|---|---|---|---|
| | ROLE | WT | ROLE | WT | ROLE | WT |
| escape capsules | | | | | | |
| separation | | | | | | |
| airplanes | | | | | | |
| fuselages | | | | | | |
| rocket exhausts | | | | | | |
| simulation | | | | | | |
| transonic flow | | | | | | |
| wind tunnels | | | | | | |
| aerodynamic characteristics | | | | | | |

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